

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXI.

MARCH 8, 1901.

No. 5

Dr. J. W. L. GLAISHER, F.R.S., PRESIDENT, in the Chair.

Robert William Chapman, M.A., B.C.E., Lecturer in Engineering and Physical Science in the University, Adelaide, South Australia ; and

Charles J. Isaac, Head of the Upper Nautical School, Greenwich Hospital Schools, and 6 Maze Hill, Greenwich, S.E.,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Jnan Saran Chakravarti, M.A., Assistant Accountant-General, Rangoon, Burma (proposed by P. Doyle) ;

Charles Sidney Mence, Teacher of Navigation and Nautical Astronomy, 49 Watling Street, E.C. (proposed by V. L. D. Broughton) ;

The Rev. John Stutter, O.S.B., Acton Burnell, Shrewsbury (proposed by A. C. D. Crommelin) ; and

Ernest George Wainwright, B.A., Lecturer in Mathematics and Physical Science, St. John's College, Battersea, S.W. (proposed by A. E. Moore).

One hundred and two presents were announced as having been received since the last meeting, including, among others :—

Galileo, *Opere*, Edizio Nazionale, vol. 8, presented by the Italian Government ; Leipzig, *Astronomische Gesellschaft Catalog*, Zone -2° bis $+1^{\circ}$ (Nicolajew), presented by the Society ; F. Nansen, *Scientific Results of the Norwegian North Polar Expedition*, pt. vi. *Astronomical Observations*, arranged and reduced under the supervision of H. Geelmuyden, presented by the Editor ; Potsdam, *Astrophysikalisches Observatorium, Photographische Himmelskarte*, Band 2, presented by the Observatory ; H. H. Turner, *Modern Astronomy*, presented by the Author.

Lantern slides from photographs of the total solar eclipse of 1900 May 28, presented by Count de la Baume Pluvinel.

On the Oxford Photographic Determinations of Stellar Parallax.
Reply to the Criticisms of Sir David Gill. By H. H. Turner,
 D.S.C., F.R.S., Savilian Professor.

In the *Annals of the Royal Observatory, Cape of Good Hope*, vol. viii. Part II., "Researches on Stellar Parallax made with the Cape Heliometer," recently published, Sir David Gill criticises adversely the observations of stellar parallax at the Oxford University Observatory in the years 1886 to 1892, saying that they "cannot be regarded as of proved value, and are certainly not reliable within limits corresponding to the probable errors assigned to them by Professor Pritchard" (Introduction, p. xv). I had nothing whatever to do with this work, which was completed and published before I succeeded Professor Pritchard as Director of the Observatory. But the reasons given by Sir David Gill for his opinion are based on the printed figures, which lead me to such diametrically opposite conclusions that I feel bound to draw attention to the matter. The main reason given for condemning the results is that the determination of scale value on the photographs is faulty. These are Sir David Gill's actual words :—

"Pritchard's method of determining the scale value would be justified if numbers of pairs of stars on the same plate were measured, and the correction for scale value was derived from the mean of all these measures instead of from only one pair. But this is precisely what Pritchard does *not* do. In his first publication on stellar parallax (*Fasciculus III., Oxford University Observations*) he measures two pairs of comparison stars for each investigation of parallax, but he derives corrections for scale value separately from the measures of the stars $a-b$ and $c-d$. It is evident that if the observations were reliable we should

have within accidental error of observation the same correction for scale value per 1000'' from the observations of both pairs ; but this is far from being the case. For example we find :—

Difference from Assumed Mean.

1886.			<i>a-b.</i>	<i>c-d.</i>
June 23	...	...	+0''·885	-0''·455
June 24	...	...	-0''·742	+1''·199

"These, it is true, are extreme cases, but *throughout the series there is little evidence of systematic agreement even in the signs of the scale-value corrections*, and their average discordance is very much greater than the probable accidental error of observation which has been derived by Professor Pritchard."

Now these figures and the statement which follows them are, in my opinion, both wrong. In the first place as regards the figures. The impression given, I think, is that they represent the correction for scale value per 1000'', whereas they are quoted for *a-b* from Table I. on p. 6, which gives the correction in 2382'' ; and for *c-d* from Table XIV. on p. 40, which gives the correction in 2066''. If Sir David Gill had read the work with more care he would have seen that Professor Pritchard has rendered the figures comparable by giving in Table XIII., on pp. 38, 39, the corrections per 1000'' for *a-b* and *c-d* side by side ; and he would also have noticed that one of the four quantities quoted by him has, by a typographical error, a wrong sign, viz. the value of *c-d* for June 24 is -1''·199 and not +1''·199. (He could also have inferred this from the column immediately preceding it on p. 40 ; three numbers following are given with wrong sign : they are, I think, the only errors of sign in the two tables.) Thus the real figures for the correction per 1000'' are as follows :—

Difference from Assumed Mean.

1886.			<i>a-b.</i>	<i>c-d.</i>
June 23	...	...	+0''·372	-0''·220
June 24	...	...	-0''·312	-0''·581

which give a very different impression from those quoted above.

It is particularly unfortunate that this Table XIII. escaped Sir David Gill's attention, for it is immediately followed by these words of Professor Pritchard :—

"The inspection of the table suggests, I think, that the principal cause of the variations in question lies not so much in accidental or local variations of the film as in actual variations in the focal length of the mirror. *This suggestion seems to me to be borne out by the general prevalence of the same sign being attached to the variations on the same night.*"

I have italicised sentences in the quotations from Sir David Gill and from Professor Pritchard in order to bring out the fact that they are directly at issue in their views of

the same figures. And now which of them is right? The point is a most important one (at least for the value of the Oxford work), and I venture to repeat Table XIII. in a slightly modified form, arranging it in order of the mean value of the two corrections instead of in order of date as given; but the dates are added, so that anyone who has not a copy of the work can reconstruct Table XIII. in its original form if he so desires. To eliminate the effect of accidental error to some extent means of every ten numbers down the series have been taken. The year is omitted from the date for brevity's sake; for though the observations extended from 1886 May 30 to 1887 May 31, there is no risk of confusion. May 30 belongs to 1886, and all other dates in May to 1887.

TABLE XIII.

Rearranged from No. III. of the Astronomical Observations made at the University Observatory, Oxford.

Date.	Variation in Measure.		Date.	Variation in Measure.	
	<i>a-b.</i>	<i>c-d.</i>		<i>a-b.</i>	<i>c-d.</i>
Jan. 5	-0.682	-0.592	Sept. 13	-0.246	-0.013
Jan. 12	-0.680	-0.542	Apr. 19	-0.274	+0.016
Jan. 20	-0.553	-0.509	Dec. 9	-0.199	-0.052
June 24	-0.312	-0.581	Nov. 23	-0.225	-0.025
Jan. 31	-0.492	-0.398	Sept. 11	-0.154	-0.080
Dec. 14	-0.476	-0.398	Nov. 5	-0.061	-0.148
Feb. 8	-0.371	-0.442	Apr. 25	-0.144	-0.047
Dec. 16	-0.570	-0.198	Nov. 16	-0.177	-0.004
May 13	-0.401	-0.336	June 28	-0.106	-0.046
Jan. 8	-0.424	-0.312	May 20	-0.198	+0.079
Mean ...	-0.496	-0.431	Mean ...	-0.178	-0.032
Feb. 17	-0.369	-0.302	Dec. 4	-0.170	+0.063
Dec. 24	-0.508	-0.136	Aug. 28	+0.095	-0.179
May 14	-0.372	-0.196	May 9	-0.038	-0.040
Mar. 16	-0.269	-0.256	Sept. 30	+0.102	-0.176
May 10	-0.202	-0.273	Aug. 20	-0.053	-0.019
Sept. 27	-0.183	-0.281	Dec. 2	-0.047	+0.003
May 5	-0.222	-0.227	Oct. 21	-0.046	+0.004
June 1	-0.175	-0.273	May 30	+0.135	-0.171
Sept. 18	-0.172	-0.262	Oct. 13	-0.017	-0.013
Sept. 15	-0.272	-0.161	June 15	-0.179	+0.155
Mean ...	-0.274	-0.237	Mean ...	-0.022	-0.037

Date.	Variation in Measure, <i>a-b.</i> <i>c-d.</i>		Date.	Variation in Measure, <i>a-b.</i> <i>c-d.</i>	
June 16	-0'102	-0'315	Apr. 26	-0'048	+0'035
Sept. 22	-0'122	-0'292	Nov. 17	+0'031	-0'035
Sept. 17	-0'220	-0'179	June 30	+0'295	-0'296
May 16	-0'360	-0'031	Aug. 30	+0'041	-0'038
May 18	-0'205	-0'186	Nov. 29	+0'016	-0'002
Aug. 29	-0'167	-0'207	Apr. 30	+0'004	+0'011
Feb. 26	-0'210	-0'150	Mar. 23	-0'093	+0'123
Dec. 7	-0'196	-0'148	Apr. 29	-0'011	+0'061
May 7	-0'134	-0'181	Nov. 3	+0'010	+0'044
Nov. 18	-0'127	-0'155	June 4	-0'126	+0'180
Mean ...	-0'184	-0'184	Mean ...	+0'012	+0'008
Oct. 2	-0'003	+0'070	Mar. 27	+0'184	+0'155
May 26	+0'011	+0'109	Aug. 31	+0'183	+0'169
Dec. 1	+0'059	+0'063	Apr. 2	+0'205	+0'170
Oct. 6	+0'029	+0'109	Sept. 29	+0'236	+0'157
Mar. 12	+0'021	+0'118	Sept. 20	+0'240	+0'184
June 23	+0'372	-0'220	July 1	+0'145	+0'316
Oct. 22	+0'094	+0'058	Mean ...	+0'180	+0'162
Feb. 25	+0'120	+0'066	Sept. 16	+0'326	+0'160
Sept. 7	-0'045	+0'238	Feb. 5	+0'212	+0'312
Jan. 10	+0'101	+0'092	June 8	+0'406	+0'223
Mean ...	+0'076	+0'070	Apr. 20	+0'223	+0'449
Sept. 10	+0'200	+0'042	Aug. 26	+0'291	+0'415
Jan. 25	+0'114	+0'136	Apr. 16	+0'558	+0'156
May 31	+0'102	+0'150	Feb. 27	+0'436	+0'303
Aug. 24	+0'191	+0'142	Mean ...	+0'350	+0'288

Collecting the means of groups, we have the following correspondences:—

<i>a-b.</i>	<i>c-d.</i>	Difference.
-0'496	-0'431	-0'065
-0'274	-0'237	-0'037
-0'184	-0'184	0'000
-0'178	-0'032	-0'146
-0'022	-0'037	+0'015
+0'012	+0'008	+0'004
+0'076	+0'070	+0'006
+0'180	+0'162	+0'018
+0'350	+0'288	+0'062

The general agreement is extremely good, although there are traces of a small systematic difference. It seems extraordinary that Sir David Gill should say : "Throughout the series there is little evidence of systematic agreement, even in the *signs* of the scale-value corrections." The most obvious supposition is that he looked at the figures so hastily as to make some mistake in assigning corresponding nights to one another. But is a hasty glance of this kind sufficient evidence upon which to condemn a great piece of work ? There are some discrepancies in the individual nights which I felt might be due to numerical mistakes in computation. I have accordingly examined the original figures (the books being still at the observatory), and have found several such errors ; but they do not materially affect the general result, and it is unnecessary to give them here. The greater part of them refer to the early observations, from 1886 May 28 to July 1. The reductions of these are mixed up with much experimental work in the determination of scale values, and in copying for the press it has, for instance, not been noticed that for the period June 23 to July 1, when a different mirror was in use, a scale value had been used for $a-b$ slightly different from that for $c-d$. When this is put right the extreme cases quoted by Sir David Gill, as well as another on June 30 (better seen in Table XIII., Table XIV. being here of wrong sign, as above remarked), disappear. But I cannot find the observations of June 28, and generally these early observations might reasonably be excluded. From 1886 August 20 the reductions are all made consistently and continuously, though there are a few errors in copying for $c-d$ from May 10-20, the removal of which would improve the agreement on May 20, not altering the other days much.

But it is not my present purpose to undertake a systematic re-examination of the whole work—merely to point out that Sir David Gill's criticisms, which refer to the printed figures, are not supported by those figures themselves.

Having set up this imaginary fault in the observations, Sir David Gill proceeds to explain it by an equally imaginary cause :—

"The obvious explanation is that in the process of development distortion of the film takes place, and this distortion is different in different position angles. As no *réseau* was employed, no means exist for eliminating the systematic error so produced except the crude assumption which Pritchard apparently adopted, viz. that this contraction of the film is proportional to the distance along any straight line passing through the centre of the plate, but different along different straight lines passing through the same centre. No attempt is made to test the accuracy or otherwise of such an assumption."

We have heard before of this distortion of the film. The *réseau* was proposed in 1887 as a means of obviating it ; and in 1888 Sir David Gill included in a large scheme for measurement of the plates an elaborate determination of this distortion on

each. His observatory has now been at work for some years on the measurement of stellar photographs, and perhaps we may soon look to him for "an attempt to test the accuracy or otherwise of such an assumption." Till we have positive evidence of some kind I for one shall venture to question the existence of this bugbear; and one of my reasons for this temerity is precisely the examination of these measures of Pritchard (or rather of his assistants), made without any réseau and yielding such accurate results. The réseau is a great convenience in measuring, but we have possibly altogether overrated its importance for the purpose for which it was invented. Of course a photographic plate is not perfect: there are all sorts of errors of a small kind—the granulation is itself a source of error, and the curvature of the glass, and its flexure, and so on. But these are of the nature of *accidental* errors, to be eliminated by taking plenty of photographs (as Pritchard did—four on each night) and measuring them under different conditions, not of *systematic* errors to be elaborately investigated. Nor did Pritchard necessarily use the different scale values in different directions because of possible distortion of the film. He did not believe in this distortion, as appears from the paragraph quoted from his work, and as I could show further by quoting from long letters to Sir David Gill, of which copies are in this observatory. But there may be very good reasons for using different scale values in different directions, quite independent of any hypothesis about distortion of the film. I mention one or two, quite on my own responsibility, not arising out of anything I have seen in Pritchard's work.

1. If the mirror or lens with which the photographs are taken is not an accurate surface of revolution (either essentially or because of flexure), its curvature in different directions, and therefore its focal length, will vary. There are obvious reasons why mirrors should err in this way more than lenses; and it is a curious fact that plates taken with mirrors *do* show some variation in scale in different directions, *e.g.* the photographs of *Eros* taken with the 30-inch mirror at Greenwich (*Monthly Notices*, lix. p. 13). If this is a *vera causa* Pritchard's rule would be essentially correct.

2. If the plate is not strictly normal to the axis of the telescope, there would be a variation in scale in different directions. But in this case Pritchard's rule would not be quite correct. If, for instance, the twist was about the line joining *ab*, then the scale value would remain unaltered for the direction *ab*, and would be altered in the direction *cd*; but the distance from *c* to the star might be increased, while that from the star to *d* was diminished, or *vice versa*.

3. If the distances on the plate in the direction *ab* were measured on a different day from those in the direction *cd*, then Pritchard's rule would be essentially correct. The small variations would then depend partly on the different expansions of the plate with temperature.

Further reasons for treating the Oxford determinations of stellar parallax with scant respect are mentioned by Sir David Gill, viz. the statements of Mr. H. S. Davis in the *Annals of the New York Academy of Sciences*, vol. x. p. 160. The following are Mr. Davis's words :—

"In the formation of Table XXIII., giving the various values of the parallax of 61 *Cygni* hitherto published, I have not placed Pritchard's values in bold type because they cannot be regarded as trustworthy. They have been discarded in taking the means of the determinations for 61¹ and 61². I have examined the eight sets of normal equations given in the work on 61 *Cygni* (pages 17–63), and among the eight sets have not found one which is correct in every quantity. The set on page 30 first attracted my attention, and so it may be used for illustration. As given there the quantities are :—

$$\begin{aligned} - 1''\cdot3140 &= +88\cdot0000x - 6\cdot7889d\mu - 2\cdot5442\pi \\ + 4''\cdot3827 &= - 6\cdot7889 + 8\cdot4762 + 9\cdot7965 \\ + 17''\cdot1716 &= - 2\cdot5442 + 9\cdot7965 + 38\cdot7724 \end{aligned}$$

These should be

$$\begin{aligned} - 1''\cdot2180 &= +88\cdot0000x - 6\cdot7889d\mu - 0\cdot9281\pi \\ + 4''\cdot3853 &= - 6\cdot7889 + 8\cdot4783 + 9\cdot7854 \\ + 17''\cdot1967 &= - 0\cdot9281 + 9\cdot7854 + 38\cdot7849 \end{aligned}$$

The criticism applies not only to the normals for 61 *Cygni*, but for many of the other stars as well. No attempt has been made to verify all the numbers in each set of normals, nor indeed to extend the test to all sets of normals given in the book ; but it can be stated that at least one number is wrong in each of the fourteen sets given on pages 17, 23, 30, 36, 47, 52, 58, 73, 75, 87, 104, 106, 107, and 113."

These remarks of Mr. Davis (which I had not been able to find until I had written the earlier part of this paper) are quite in accordance with my own experience of the work. It certainly contains far too large a number of numerical mistakes, and I have spent too many years detecting and correcting such errors to feel any inclination to defend or condone them. If Mr. Davis insists on rejecting this work because of such errors, and of the general mistrust which their existence inevitably causes, I for one shall not attempt to question his legal right to do so. I would only remark that it is quite possible to over-estimate the importance of such errors and the effect they have on the result. They are of the nature of accidental errors, and will increase the probable error ; hence they do not give any false appearance of accuracy. And as regards the main result, it is wonderful how little this is often affected by the correction of such errors when the total number of observations is large. Those who have had experience of examining masses of observations know this well.

The example given by Mr. Davis involves corrections of about $-0''.008$ to α , $-0''.007$ to $d\mu$, and barely $+0''.001$ to π . If this example is really representative we may consider the parallaxes as given sensibly correct; for no one attaches much importance to $0''.001$ or even to $0''.01$. Parallaxes quoted by Mr. Davis with approval in the table from which he excludes Pritchard's measures range from $0''.20$ to $0''.52$.

Description of a Floating Photographic Zenith Telescope and some Preliminary Results obtained with it. By Bryan Cookson, M.A.

The instrument which is described in this paper was constructed with a view to undertaking a determination of the constant of aberration by Küstner's adaptation of the Talcott Method. Observations for this investigation have not yet been begun, but a description of the instrument and of some preliminary results obtained with it may be of sufficient interest to justify its publication.

In the usual form of zenith telescope the level is the essential part; in the present case the level is abolished and the verticality of the axis, about which the instrument is rotated, is assumed by floating the support of the telescope in a bath of mercury.

The correctness of this assumption is shown in the paper. The principle of floatation was employed as long ago as 1825 by Captain Kater in his floating collimators (*Phil. Trans.* 1825 and 1828), but seems to have been forgotten till Dr. Chandler adopted it in 1884 and applied it with great success to an instrument of very novel design which he called the almucantar. It was shown by Dr. Chandler that the floating part of his instrument returned after disturbance to within $\frac{1}{20}$ of a second of arc of the original position; that is, it resumed its original inclination to the horizon with a higher degree of accuracy than the bubble of a sensitive level would do. A zenith telescope, then, which depends on the principle of floatation might reasonably be expected, other things being equal, to give better results than one which depends on a level. In 1891 the Georgetown College Observatory erected a floating zenith telescope (a short description of it will be found on pp. 43 to 56 of the publications of that observatory): the results obtained with it seem to have been satisfactory. This is, so far as I know, the only floating zenith telescope which has hitherto been made. Two large almucantars, however, have been recently constructed, one by Professor Sampson at the Durham Observatory (*Monthly Notices*, vol. lx. p. 572), the other by Professor Howe at the Case Observatory, Cleveland, U.S.A. (*A.J.* vol. xxi. p. 57). Results obtained with these instruments have not as yet been published.

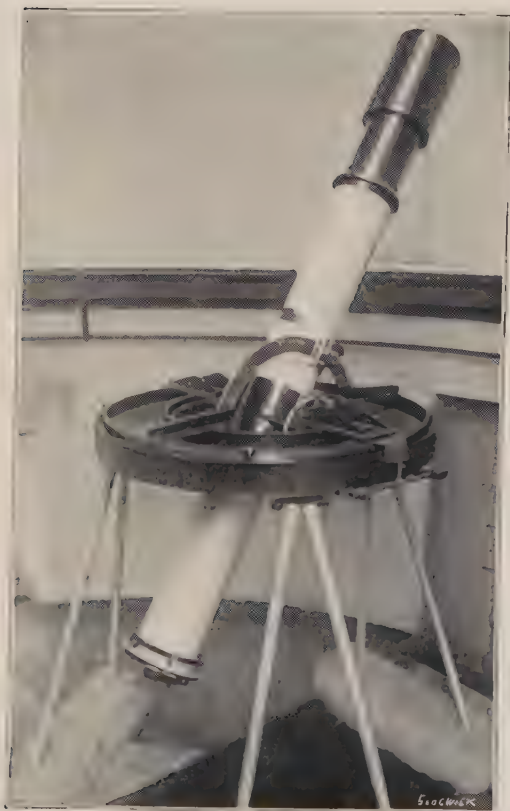
I believe there are also two instruments exactly similar to Dr. Chandler's second and larger almucantar which are in regular use in America. This completes the list of astronomical instruments actually constructed on the floatation principle.

A photographic zenith telescope of the usual form and dimensions was set up in 1895 at the Berlin Observatory, and the latitude determined with it by Dr. Marcuse, who obtained results quite as accurate as those with the visual telescope. In the case of the instrument now to be described the photographic method was adopted on account of the difficulty anticipated in the divining of some form of micrometer for use with a floating telescope, and also because, as the instrument has only to be approached in order to rotate it, there is much less chance of the heat of the observer's body affecting its condition than if he were close up to it, making bisections with the micrometer. There is also the advantage common to all photographic methods of having a permanent record of observation in the photographic plate which can be measured and reduced at the convenience of the observer. The quantity to be measured is the perpendicular distance of the marks or trails which the stars make on the sensitive plate by virtue of their diurnal motion. The results obtained by Marcuse were satisfactory in showing that the accuracy of measurement of star trails was of a high order; indeed it might be expected that a star trail on a photographic plate could be set upon at any rate as accurately as a moving star in a visual telescope, although this can be done by a skilful observer with surprising accuracy.

Description of Instrument.—It will be best first to give a general idea of the form of the instrument. There are three principal parts—the trough, the float, and the telescope. The trough and float are shallow annular basins; the float is concentric with the trough, and fits inside it with half an inch clearance all round. Mercury is poured into the trough, and the float is free to take up its position of equilibrium in the bath of mercury. The telescope passes through the centre of the annulus, and its trunnions rest in V's, which are carried by the float. The trough is fixed, but the float is free, and can be rotated in azimuth.

It was decided to adopt the annular shape for the trough and float for two reasons: first, because the rotation of the telescope about the vertical could be most easily performed by moving the float round inside the trough; and secondly, because the float could be rotated exactly through 180° by always bringing two points on it opposite two fixed points on the trough. It follows from this and the fact that the axis of rotation is vertical that the line of intersection of the plane of the meridian with the plane of the photographic plate is the same line on the plate before and after rotation.

The trough, A, and float, B (Plates 8, 9), are of cast iron, and the whole of the outside of the latter is turned and polished. The out-

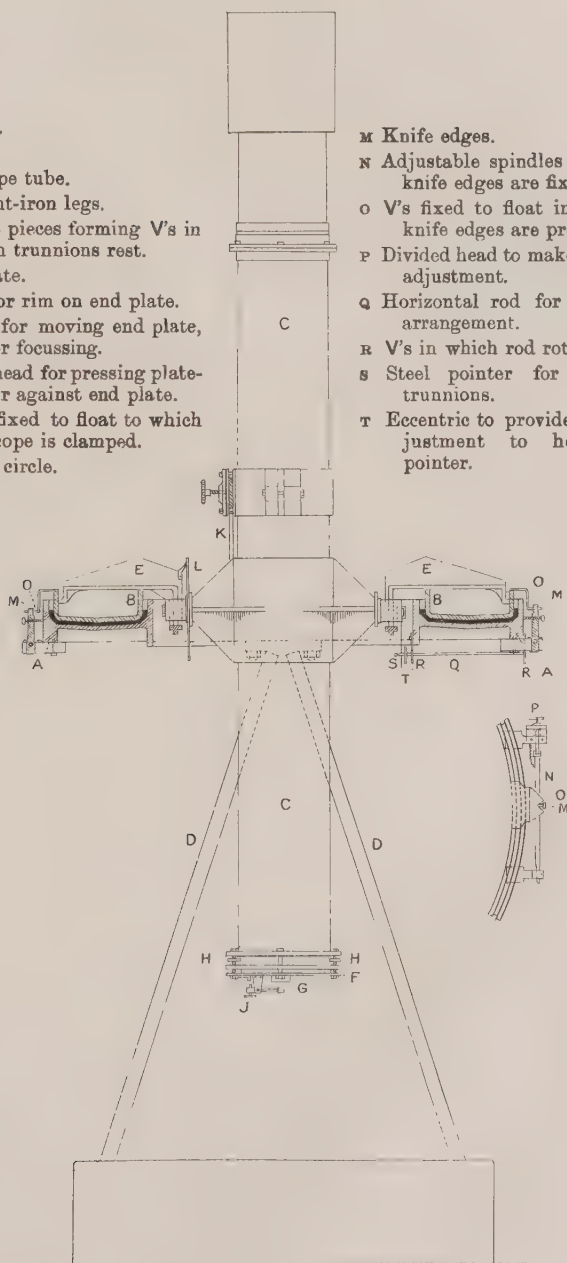


FLOATING PHOTOGRAPHIC ZENITH TELESCOPE.

BRYAN COOKSON.

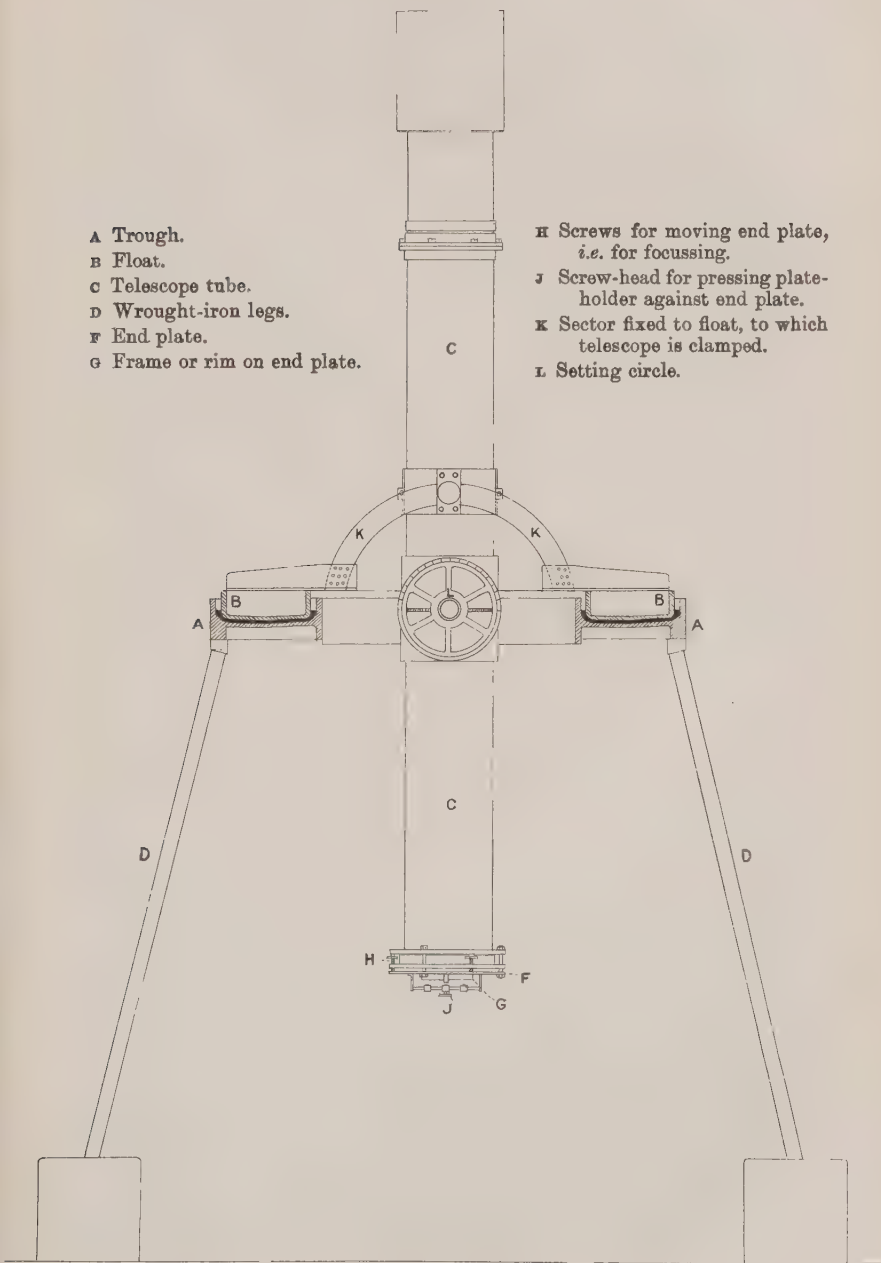
- A Trough.
- B Float.
- C Telescope tube.
- D Wrought-iron legs.
- E Bracket pieces forming V's in which trunnions rest.
- F End plate.
- G Frame or rim on end plate, *i.e.* for focussing.
- H Screws for moving end plate, *i.e.* for focussing.
- J Screw-head for pressing plate-holder against end plate.
- K Sector fixed to float to which telescope is clamped.
- L Setting circle.

- M Knife edges.
- N Adjustable spindles to which knife edges are fixed.
- O V's fixed to float into which knife edges are pressed.
- P Divided head to make azimuth adjustment.
- Q Horizontal rod for levelling arrangement.
- R V's in which rod rotates.
- S Steel pointer for touching trunnions.
- T Eccentric to provide fine adjustment to height of pointer.



- A Trough.
- B Float.
- c Telescope tube.
- D Wrought-iron legs.
- F End plate.
- G Frame or rim on end plate.

- H Screws for moving end plate,
i.e. for focussing.
- J Screw-head for pressing plate-
holder against end plate.
- K Sector fixed to float, to which
telescope is clamped.
- L Setting circle.



side diameter of the float is 39 inches, the inside 24 inches, and there is $\frac{1}{4}$ inch of mercury between the trough and float, except at the free surface where there is $\frac{1}{2}$ inch. The float is $\frac{3}{8}$ inch thick, weighs very nearly 150 lb., and its cross-section is slightly V-shaped at the bottom to assist small bubbles of air in the mercury to escape from under it. About 142 lb. of mercury are in use, and the whole of the floating parts weighs 350 lb. To prevent the float from knocking against the trough whilst being rotated, a circumscribing polygon of wire is attached to the trough and stretched round the float, so as just to clear it when it is in position. This wire acts as a spring, so that the float suffers no jarring knocks against the sides of the trough.

The trough is supported by three pairs of wrought-iron rods, D, $1\frac{1}{4}$ inch in diameter, each pair forming an inverted V. The plane of these V's slopes outwards from the trough to give clearance room for the telescope when it is being rotated at considerable zenith distances, and also to increase the stability of the support. The height of the bottom of the trough above the floor is 4 feet 6 inches, and the maximum zenith distance at which the telescope can be rotated is 45° .

The telescope is carried in the centre of the annular float by means of two overhanging cast-iron bracket pieces, E E, forming the V's in which the telescope trunnions rest. The tube C is brass, $\frac{1}{8}$ inch thick and $7\frac{1}{4}$ inches internal diameter. The upper end carries the object glass attached to a flange, and at the lower end there is a circular end plate, F, perforated by a rectangular aperture which is slightly smaller than the sensitive plate, and which admits the light from the object glass to it. This aperture is surrounded by a raised rim or frame, G, $\frac{1}{2}$ inch deep, against which the plate is pressed during exposure. The focussing is effected by means of three screws, H, which move the end plate relatively to the telescope tube: their pitch is 1 mm., and they have divided loads so that the focus can be set to 0.01 mm. These screws also regulate the tilt of the photographic plate to the optic axis of the lens; and once the focus found and this adjustment made, they are clamped.

The instrument is used for photographing the trails of stars across the meridian; the point on the trail corresponding to the moment of meridian passage is marked by a gap or break in the trails. This gap is the shadow cast by a thin copper wire, about 0.1 mm. in diameter, which is attached to the above-mentioned frame so as to lie just level with the top of it. Means are provided for making the necessary adjustment to bring this wire into the meridian. There are also two similar parallel side wires, each distant 9 mm., or 75 equatorial seconds from the central wire.

There are six plate holders made of brass, and they fit like a lid on to the frame of the plate aperture. They are held in this position by a simple arrangement, and after the dark slide is drawn are pressed home by simply turning a screw head, J, so

that the sensitive plate rests against the frame, G, on the end plate ; the frame then lifts the plate off the ledge in the holder, and springs at the back of it press the plate at three points against three small steel points let into the frame on the end plate. In this way every plate is exposed at exactly the same distance from the object glass. The marks on the gelatine made by the steel points are useful in showing the position in which the plate was exposed.

A great deal of trouble has been found in devising an efficient clamp to hold the telescope relatively to the float, and a new one has recently been added. The original clamp, with a slow-motion screw, acted on one of the trunnions, and its arm was held by one of the bracket pieces which carry the telescope. The origin of the trouble was eventually proved to be in the bracket piece itself : it was not sufficiently rigid, acting through the short arm of the clamp, to make the telescope exactly respond to the rapid changes of direction of motion which the float undergoes when executing its metacentric oscillations, and this of course entirely vitiated all results for the latitude. In the new clamp the telescope tube itself is clamped to a circular sector, K, which is firmly fixed to the float : this arrangement has been found to perform most satisfactorily. The old clamp with its slow-motion screw can be used for setting to the required zenith distance.

The brass finding circle, L, 9 inches in diameter, is a very simple and inexpensive one : it is divided to half a degree and the setting is made to $0^{\circ} \cdot 1$ simply by a pointing index, which is quite sufficient for all practical purposes. The divisions are cut on a strip of celluloid let into the brass circle.

A few words must be said concerning the object glass. A good deal of time and trouble was taken over the choice of a lens, and it was eventually decided, after making some experiments, that a Cooke lens, Series I. c (Taylor's patent), of $6\frac{1}{2}$ inches clear aperture and 65·4 inches focal length, would be most suitable. This lens has a flat field of 14° diameter, but owing to the distance between the first and third component lenses not more than half its field is illuminated with full aperture, though for its present purpose this is no disadvantage, as the maximum angular distance that is covered by the plates is $3^{\circ} \cdot 2$. The performance of this lens is satisfactory in the highest degree : the star trails are wonderfully sharp and distinct. Though the curvature of the middle lens—a negative flint—is considerable, the change of focal length with temperature is small, because the part due to altered refractive index is compensated by that caused by change in the separation of the component lenses. I have calculated the change due to a rise of temperature, and find that the sensitive plate, which is connected to the lens by means of a brass telescope tube, will be removed just over $0 \cdot 01$ inch from the focus for a rise of 10° C. Observations made to determine the focus are in complete accordance with Lord Rayleigh's

formula,* and show that this is just the limiting displacement possible without impairing definition.

The three instrumental adjustments are: 1. Azimuth. 2. Level. 3. Collimation.

1. When the instrument is being used for observations the float must be held in azimuth, so that the axis of the telescope shall be in the meridian, but in such a way that there shall be no force to restrain its free oscillatory motion in the plane of the meridian. Two points therefore at the ends of an east and west diameter are held in the following manner: Knife edges, MM, are fitted to horizontal spindles, N, which are held by the trough, and are pressed by weak springs into two V's, OO, fixed to the float. The knife edges can be pulled back out of the V's, and their positions are adjustable by means of screws with divided heads, P, so as to bring them into the correct azimuth. In this way the only line in the float which is held is the line joining these V's, and it is so arranged that this line lies in the surface of the mercury. There can thus be no force to restrain motion of the telescope in the meridian, and the frictional force of the knife edges in the V's is too small to affect the inclination of the horizontal axis of the telescope appreciably. To change the azimuth by $0^{\circ}.5$, each adjusting screw must be turned through one division of its divided head.

2. It did not seem advisable to employ the usual striding level to test the inclination of the horizontal axis, because the application of it would change the inclination of the floating instrument. The limit assigned to the level error is $\pm 1^{\circ}$, which corresponds to 0.03 mm. at an arm equal to the distance between the trunnions, viz. 20 inches, and no very elaborate arrangement is therefore required. The method adopted is to bring first one and then the other trunnion over a fixed arrangement for touching them, and thereby finding when they are at the same height over it. It consists simply of a horizontal rod, Q, which turns in V's, RR, fixed to the trough. Through the end of the rod, and perpendicular to its length, runs a stiff steel wire, S, and by rotating the rod with the fingers it can be felt with great nicety when the point of the wire just touches the trunnion. By mounting the rod eccentrically in a pulley-wheel which turns in the V, and moving the rod in this eccentric, the necessary fine adjustment is provided. The diameters of the trunnions do not differ by 0.01 mm.; and as the fingers can feel a difference of 0.01 mm. in the height of the trunnion over the touching point, it is clear that this arrangement enables the adjustment to be made with the necessary accuracy. A sliding weight is attached to one of the bracket pieces on the float, and is moved till the pointer passes both trunnions with the same ease.

3. To correct for collimation error, the frame carrying the three transit wires can be moved by loosening the screws which attach it to the frame on the end plate.

* *Phil. Mag.* Series V. vol. xx. p. 355.

With the exception of the object glass and the trough and float, the instrument was made by the Cambridge Scientific Instrument Company, and I wish to express my deep sense of gratitude to Mr. Horace Darwin for all the care he has devoted to its construction, and for the many ingenious devices which have so largely contributed to the success of the instrument.

My thanks are due to Messrs. Cooke and Sons for much valuable information, and for the loan of a lens with which to make experiments; also to Mr. Norman Cookson and the Hon. C. A. Parsons for the casting and turning of the trough and float.

The instrument is mounted in a dome at the top of the main building of the Cambridge University Observatory. This dome, and the instrument it contained, had long been out of use. Sir Robert Ball had the old telescope removed and the dome put into thorough working order, and offered me the use of it. I wish to express my best thanks to him for this and for many other kindnesses.

The diameter of the dome is 15 feet, and it can be easily pushed round by hand. The aperture of the dome is opened by three independent shutters which are pulled aside by cords, and the exposures on the stars are made by opening the appropriate shutter at the proper moment. Windows are provided for efficient ventilation of the dome. The mean difference between the temperature of the outside and of the inside air is found to be $1^{\circ}5$ C.

The Measuring Micrometer.—To determine the linear distance between the trails on the plate, one of Zeiss's Standard "Comparators" is used: with this instrument distances up to 100 mm. can be measured. A division on its micrometer head represents 0.001 mm., which corresponds to 0".12 on the photographic plate; consequently the last or estimated figure in a reading is the equivalent of 0".01. In the microscope for viewing the trails there are four horizontal and two close vertical wires, and the plate is moved by a slow-motion screw till the trail bisects the space between the vertical wires. This is done at eight different points on the trail, four on each side of the meridian break at equal distances from it. The horizontal wires, corresponding to the vertical wires in a visual telescope, are used to indicate these points. With the magnifying power which is always used, viz. 24, the distances of the eight points from the meridian break are $\pm 1^{\circ}4$, $\pm 2^{\circ}7$, $\pm 4^{\circ}1$, $\pm 5^{\circ}5$.

This instrument belongs to Mr. Newall, who very kindly allowed me to use it, and to have the system of wires described above put into the eyepiece. I wish to sincerely thank him for this, and also for the encouragement and advice he has always been ready to give.

In measuring, the eight settings on a trail are all made before moving to the next star. Each point is set upon twice, though lately through pressure of time the bisection has been made only

once. Preliminary experiments show that there is no systematic error depending on the direction in which the trail is brought between the vertical wires, or depending on the direction in which the plate is measured.

The division errors of the silver scale have been fully investigated by Mr. Newall, who has determined the error of every division and constructed a table of them. The error of run was found to be negligible, and the errors both periodic and progressive of the micrometer screw over the part of it in use only amount to one or two estimated places on the screw head. The only correction that is applied to the micrometer readings is therefore that for error of division. The correction for temperature, arising from the difference of expansion of the glass plate and the scale, amounts to one part in 100,000 per degree centigrade, which corresponds to $0''.01$ in an arc of $21'$. Excepting in the most careful measurements, no account is taken of this.

Plates and Development.—The plates in use are Ilford Empress and Ilford Special Rapid, and all those intended for measurement are on patent plate glass. The developer has always been Metol. The Special Rapid plates are twice as fast as the Empress, and from exposures on the *Pleiades* made within a few minutes of one another, it was found that measurable trails were obtained of stars of magnitude 7.4 on Pickering's scale with the faster plate, as compared with those of magnitude 6.9 with the slower. Trails of zenith stars of magnitude 7.8 are quite easily measured on the Special Rapid plates; the grain of these plates has caused no inconvenience in the measurement.

The size of the plates is 5×2 inches.

Adjustments.—The errors of collimation and azimuth can be determined either visually or photographically, after the axis of the trunnions has been levelled in the way described above. For visual observations a negative eyepiece is fitted to the frame, G, on the end plate, and transits of suitable stars over the central wire are observed. The collimation error is found from the times of transit of two stars, culminating within a degree of the zenith, one star having been observed with the circle west, the other circle east. With the collimation error thus determined the azimuth error may be found by observing the transit of a polar star. The photographic method is, however, the easier of the two, and gives much better results. The instrument in this case is practically used as a photographic transit circle. The procedure is very similar, excepting that the collimation error of one of the side wires is determined from one star independently of the star's right ascension, the clock error and the azimuth error. Breaks in the trails are made at noted times by putting a cap before the object glass, and the distances of these breaks from any of the three wires are measured at the micrometer.

As it is important to know the limits within which the errors

must be kept, in order that their effect on the latitude deduced from a Talcott pair of stars may not amount to $0''.01$, the following expression for the correction due to errors a , b , c of azimuth, level, and collimation respectively was found:—

$$\delta\phi = D(a^2 \cos^2 \phi + b^2 \sin^2 \phi + c^2) + Abc + Bca + Cab + \frac{\sin 2\phi}{2}(b^2 - a^2)$$

where

$$D = \frac{1}{2} \frac{\sin 2\phi}{\cos \delta_s \cos \delta_n} \quad B = \sin 2\phi \frac{\sin z}{\cos \delta_s \cos \delta_n}$$

$$A = \sin 2\phi \frac{\cos z}{\cos \delta_s \cos \delta_n} \quad C = \sin 2\phi \frac{\sin z \cos z}{\cos \delta_s \cos \delta_n}$$

and δ_s , δ_n denote the declinations of the south and north stars respectively, and z is their mean zenith distance. It will be found from this formula that $\delta\phi$ will not amount to $0''.01$ if a , b , c are kept within the limits $\pm 1''$. These limits are smaller than those usually assigned, but the reason of this is that the part of $\delta\phi$ depending on the products of the errors is generally neglected.

An attempt was made to find the level error by observations of stars at zenith distances, varying from 36° N. to 52° S.; the error of the chronometer was otherwise known. The resulting error was $-0''.5$, circle west: this shows that the method adopted for levelling the axis of the trunnions performs satisfactorily.

No appreciable difference can be found between the azimuth error for circle west and that for circle east. At present it amounts to $+0''.45$.

The errors of collimation at the ends of the central wire are $-0''.46$ and $-0''.05$ circle west. The wire is therefore inclined at an angle of $0''.03$ to the meridian, the effect of which is quite inappreciable. The side wires are distant $75''.0$ equatorial seconds from the middle wire, and they do not deviate by more than $0''.05$ from parallelism to it. No correction has therefore to be applied for collimation error of any of the three wires.

Scale Value.—Though the accurate and definitive scale value is not required in the present paper, yet it may be worth while to present the result of measurements to give an idea of the degree of accuracy attained in the measurement of trails, and to show that the optical distortion of the lens is at any rate small up to the $1\frac{1}{2}^\circ$ from the centre of the field. This is a point, however, which requires further careful investigation. The scale values derived from seven pairs of stars in the *Pleiades* are given in full in the table below. The positions of the stars were taken from Elkin's *Memoir, Yale Observations*, vol. i. Part I. p. 87, and ten measurements have been made from the star h and not η (*Alcyone*), as is usually done, because it was anticipated that the closeness of the trails of η and b (*Electra*) would interfere with measurements of η . The focussing screws have not been

touched or the telescope interfered with in any way during the interval in which these photographs have been taken. The values deduced from them are therefore comparable *inter se*.

Date.	<i>h</i> -28. mm. 20'7.	<i>h</i> -34. mm. 12'2.	<i>h</i> -d. mm. 5'6.	<i>c</i> - <i>h</i> . mm. 6'5.	<i>e</i> - <i>h</i> . mm. 9'3.	<i>k</i> - <i>h</i> . mm. 11'9.	<i>m</i> - <i>h</i> . mm. 20'1.	Daily Mean.	Temp. Telescope Tube. C.	Position of Circle.
Nov. 27	124''627	''599	''531	''725	''614	''636	''606	''620	+6°7	E.
Dec. 7	''571	''632	''588	''643	''628	''647	''638	''621	6'4	W.
13	''594	''605	''606	''586	''598	''622	''633	''606	7'2	W.
14	''633	''629	''689	''477	''576	''582	''605	''599	9'2	W.
16	''638	''624	''642	''579	''628	''580	''582	''610	6'1	E.
Jan. 14	''589	...	''589	''585	''646	''648	''617	''612	3'3	E.
18	''619	...	''622	''618	''623	...	...	''621	5'0	W.
Mean	124''610	''618	''610	''602	''616	''619	''614	124''612		
Jan. 29	''581	''614	''687	''655	''641	''662	''631	''639	3'8	W.
31	''619	...	''650	''579	''544	''583	''573	''591	3'6	W.
Feb. 1	''621	''646	''601	''464	''560	''542	''569	''572	4'0	E.
Mean	124''607	''630	''646	''566	''582	''596	''591	124''601		

Under the names of the stars the approximate distance in millimetres is given; the angular distances in minutes of arc may be roughly found by multiplying by 2. These values have been corrected for geometrical distortion, due to the fact that the photograph is a plane projection of the celestial sphere; and to see if there was any marked optical distortion, the last three plates were exposed with their centres 1° from the star *h*. From the first seven plates the probable error of a single determination comes out as $\pm 0''.0256$; that of the mean of seven is therefore $\pm 0''.0096$, and of three $\pm 0''.0148$, so that the two means for each pair agree within the limits of their probable errors. An attempt was also made to find the distortion by measurements of some other stars whose positions were well known. Their declinations were taken from Newcomb's *Catalogue of Fundamental Stars*, and the following scale values were derived:—

Stars in Taurus. Z.D. 36°2 S.			Stars in Perseus. Z.D. 3°5 S.			Stars in Auriga. Z.D. 34° S.		
α -80	25'7	124''576 4	λ - μ	55'6	124''633 4	ϵ - η	74'4	124''613 4
δ - α	28'9	''637 4	λ - c	76'1	''629 4	ϵ - ζ	79'3	''612 3
68- α	40'2	''620 4	c - μ	20'5	''610 4	ζ - η	4'9	''420 3
α - ρ	48'4	''602 4						

After the names of the stars the approximate distance between the trails is given in millimetres, and after the scale value the

number of plates taken. It will be seen that very considerable arcs have been measured—the largest is $2^{\circ} 45'$ —and if there were any distortion its effect would be greatest on these large distances. I tried to deduce from all these results by least squares an expression of the form $bs^2 + cs^3$ to represent the distortion, but the coefficients b and c came out smaller than their probable errors. No explanation has at present suggested itself for the abnormally small value $124''\cdot420$ derived from the standard stars ξ and η *Aurigæ*. It may, however, be safely concluded that the optical distortion of the lens over the field at present in use is very small, and a considerable series of very careful measurements would be required to show it.

For the present it will be sufficient to take as the scale value that derived from the *Pleiades* stars, namely $124''\cdot610 \pm 0''\cdot0034$.

Accuracy of Measurement.—The probable error of a single bisection of a star trail has been determined for three separate cases :

1. Star on meridian, float fixed so as to prevent oscillations.
2. Star on meridian, but float not fixed.
3. Star on one of the side wires and float not fixed.

In the first two cases the trail is practically parallel to the vertical wires in the microscope, but in the last the curvature of the star's path is very marked, and it was thought that this might interfere with accurate setting. Corrections having been applied for curvature of path, the probable errors of a single bisection are as follows :—

	Probable Error.	Number of Trails.	Zenith Distance.
1. Star on meridian, float fixed	$\pm 0''\cdot17$	34	$28^{\circ}5$
2. Star on meridian, float not fixed	$\pm 0''\cdot17$	37	$28^{\circ}5$
3. Star on wire 75° from meridian, float not fixed	$\pm 0''\cdot14$	22	$0^{\circ}5$

The small difference between these probable errors may be referred to the greater refraction irregularities that naturally occur in the trails of stars of greater zenith distance, and the accuracy of setting may be taken as equal in all three cases.

Now it often happens that there are perceptible traces of oscillatory motion of the float to be seen in the trail when viewed with the measuring microscope, and though a wind screen has been erected round the instrument, it seems almost impossible to entirely prevent minute oscillations from arising. The existence of undulations with an amplitude of about $0''\cdot25$ on the plate makes the trail apparently easier to set upon, but it was feared that the result might not be reliable. The equality of the probable errors in the three cases above proves, however, that neither the existence of minute undulations of the trail, nor the curvature of the star's path, nor both combined have any deteriorating effect on the accuracy of setting on a star trail.

But the accuracy of setting is far from being a true indication of the accuracy to be expected in making measurements of the same distance at different times. The probable errors, therefore, of the distances measured for scale value have been determined; for this purpose the distances have been divided into three groups, and the error found for each. The sum $[vv]$ is formed for each distance, and the probable error for the group found by the usual formula

$$p.e. = 0.67 \sqrt{\frac{\sum [vv]}{m-n}}$$

m being the total number of measures, n the number of separate means. The probable errors thus derived from all the stars observed for scale value are:—

mm.	Distance.	Probable Error of One measured distance.
	arc.	
0-15	0'-31'	± 0.218
15-30	31'-62'	± 0.358
30-80	62'-166'	± 0.503

These results are deduced from plates exposed when the float was fixed, and are therefore independent of the fact that the instrument is floating; it might, however, be imagined that if the float were free the inclination of the telescope to the horizon would be changed between the transits of the stars by a disturbance of the instrument caused by the wind. The corresponding probable errors for the case of the free float have therefore been determined in the same way.

Distance.	Probable Error.
mm.	"
0-15	± 0.206
30-65	± 0.486

There are not sufficient measurements to give a reliable error for the distances 15-30 mm. The agreement of the values for the two cases of a fixed and a free float shows that the fact that the instrument is floating does not interfere with the accuracy of measurement. This is a satisfactory indication of the remarkable stability of floatation of the instrument.

Distortion of Film.—In connection with the accuracy of measurement some experiments were made to see if any appreciable part of the errors of measurement were likely to arise from this source. Six contact photographs of a glass scale were taken, and after having been treated in various ways were measured together with the scale and compared with it. The plates were developed in Metol for periods varying from two to eleven minutes, and after having been fixed were washed in running water. The total length of the scale was 100 mm., and the

maximum difference in the length of the photograph and of the scale amounted to 0.0071 mm.; a difference in a length of 5 mm. amounting to 0.0029 mm. was found in one instance. The mean differences for lengths of 5 and 15 mm. for the six plates measured are given, together with details of treatment of plates.

Plate.	Mean Diff. expressed in 5 mm.	Photograph and Scale, 0.0001 mm. 15 mm.	Deve- loped.	Washed.	Dried.
			m	h	
D. 3.	9.3	17.2	3	6	slowly
D. 6.	6.5	7.5	2	13	very quickly (2 ^h)
D. 7.	6.6	10.4	2	13	6 hours
D. 8.	9.1	20.7	2	5	slowly
D. 9.	7.8	11.7	4	2	slowly
D. 10.	8.2	9.9	11	2	slowly
Mean	7.9	12.9			

The distortion of the gelatine film does not appear from these measurements to depend on the treatment of the plate within the range of treatment here considered, and is more likely to depend on the evenness and regularity with which the emulsion is applied to the plate.

Oscillations and Stability of the Float.—The oscillations of the float are of two kinds: one is connected with the wave motion of the mercury in the trough, and the other is simply the meta-centric oscillations of a floating body. It is from these last that a measure of the stability of the float can be derived, but in the practical working of the instrument they are of no importance compared with the first. Both kinds can be very conveniently studied photographically.



The photograph which is here reproduced was obtained by suspending a weight from the float and suddenly lifting it. The effect of this is to set up the wave motion in the mercury which the figure shows. Measurement of this and other negatives, showing oscillatory motion, has proved that the period—viz. 9.40—is constant for all amplitudes. It is of some interest to compare this period with that for the free-wave motion in an annular trough of the same dimensions as the present one. In a paper to be published elsewhere I have done this, and proved that the longest period is 18.6 when there is one nodal diameter. The ratio of two successive amplitudes on the same side of the position of equilibrium is constant, and equal to 0.76, and it was found

that no trace of any disturbance producing an initial amplitude of 3.5 mm. could be seen after 206 seconds. Representing, then, the motion by the usual equation for damped oscillations, namely,

$$\frac{d^2x}{dt^2} + 2a\frac{dx}{dt} + bx = c$$

these data are sufficient to show that an initial disturbance of amplitude x mm. on the photographic plate will have no appreciable effect on the trail after τ seconds, where

$$\tau = 169 + 30 \log_e x.$$

The rotation of the instrument between the two stars of a Talcott latitude pair sets up oscillations with an amplitude of about 0.25 mm., and takes 20^s to perform. In this case τ is therefore 127 seconds, and hence the right ascensions of the two stars must differ by two and a half minutes if the trails are to show no undulations. But as the rate at which the oscillations are damped is known, there seems to be no reason why undulatory trails should not be used for even the most careful measurements, for it is quite as easy to set on the crests and hollows of the waves of such a trail as on a perfectly steady one. This, however, has only been done in a few cases, and no definite conclusion can yet be stated.

To find the period of the other kind of oscillations—viz. the metacentric—it is only necessary to know the metacentric height, MG, and the radius of gyration, K, of the floating part of the instrument. In the present case MG is 10.9 feet, and K 1.8 foot. The formula

$$\tau = 2\pi K \sqrt{\frac{I}{g \cdot MG}}$$

therefore gives 0^s.6 for the period of the metacentric oscillations. In the figure above these oscillations show themselves in the small dots which can be seen in the first upward stroke; and, by counting them, it is found that their period is 0^s.6, showing satisfactory agreement with theory. Direct visual observations give the same result.

The moment required to produce a tilt θ of the float is $g\rho Ak^2\theta$, where ρ is the density of the fluid, A the area of the plane of floatation, and k its radius of gyration. (The distance between the centres of gravity of the floating body and of the displaced fluid is neglected.) It follows that a moment of a pound-foot will produce a tilt of 52'', which corresponds to a movement of the outside of the float through 0.005 inch; in other units a tilt of 1'' is produced by a moment of 260,700 centimetre degrees. Now the forces which prevent the float from returning to exactly its old position after disturbance most probably arise from differences in the surface tension of the mercury before and after disturbance. The tension of the surface of pure mercury and air is

500 degrees per linear centimetre, and it seems hardly likely that the tension of more than 10 centimetres of mercury in contact with the float could be changed by the disturbance, or even by rotation to the extent of 100 degrees per centimetre. It follows from this that the float may be expected to return to within $0''.10$ of its old position; if merely shaken, to within a few hundredths of a second; and observation proves that this is really the case.

It was for directly investigating this point that three transit wires were mounted instead of only one. Their distances are such that a star in the zenith takes just four minutes to cross all three; and one method of observing is to allow two stars, which differ in right ascension by from four to eight minutes, and in declination by a few minutes of arc, to register their trails over both the side wires. The instrument is not touched during the transit of the first star, but is shaken or rotated through 360° between the transits of the second star over the two side wires. The trail of the first star serves as a reference line from which to measure the distance of the second trail at the points where it crosses the wires. We can thus directly discover whether any change of inclination of the telescope has been caused by the disturbance. This has been done with the following results.

Three plates were exposed, on which appeared the trails of six stars, whose declinations were all within $30'$ of one another. Between the transits of three of them over the side wires the float or telescope was pushed by hand, but for the other three the instrument was not touched. The only reduction of the measurements that is necessary is to apply to both undisturbed and disturbed trails the mean difference between the readings at the two wires for the undisturbed trails in order to correct for the shift of the plate relatively to the scale of the micrometer in moving from one wire to the other. If there were no errors of measurement the shift of the plate, as shown by the three undisturbed trails, should be the same. The actual figures are as follows:—

	Undisturbed.		Disturbed.	
	$0^{\text{mm}}.0001$	Arc.	$0^{\text{mm}}.0001$	Arc.
Jan. 29	+ 3	+ $0''.04$	- 19	- $0''.24$
	- 24	- 0.30	+ 22	+ 0.27
	+ 22	+ 0.27	- 4	- 0.05
Jan. 31	+ 8	+ 0.10	- 16	- 0.20
	+ 8	+ 0.10	+ 6	+ 0.07
	- 17	- 0.21	0	0.00
Feb. 1	+ 21	+ 0.26	+ 12	+ 0.15
	- 4	- 0.05	+ 5	+ 0.06
	- 16	+ 0.20	- 29	- 0.36

The sums of the squares of these residuals are almost identical, and this shows that the accuracy of floatation is, at any rate, as great as that of the measurement of the trails.

To test the effect of not merely shaking the float but of rotating it through 360° , four other pairs of stars in about declination $+58^\circ$ were chosen and observed in the same way, but for the addition of the complete rotation. The figures given below are the excess of the distance between the trails before rotation over that after rotation; the approximate distance is also added.

	I.	II.	III.	IV.
	20'.1	9'.4	27'.9	7'.6
Jan. 29	-0''.21			
31	-0''.51			
Feb. 2		+0''.20	+0''.80	-0''.76
3		-0''.15	+0''.35	+0''.19

The rotation of the float and telescope was purposely not made with any particular care, so that the performance of the instrument is very severely tested. Now the mean of these eight differences, regardless of sign, is $0''.40$, and the mean formed in exactly the same way for the three undisturbed trails above is $0''.30$, the total distance for these last being only one-seventh of the total distance of the trails in the present four pairs of stars. This leads to the satisfactory conclusion that even a complete revolution of float and telescope does not appreciably disturb the inclination of the telescope to the vertical. With regard to the accuracy of measurement here indicated, it is interesting to note that the probable errors found for a single bisection of a trail or of a measured distance compare very favourably with those found by other observers with different but comparable instrumental means.

To test the stability of floatation yet further a method has been devised to investigate the effect of a half revolution of the float—a rotation through 180° ; and this case is really of the most interest because it is that which actually occurs in observations of the latitude. The method is as follows: A star culminating within $1^\circ 20'$ of the zenith is allowed to register its trail over the first side wire, the telescope being clamped and pointed exactly to the zenith; the float and telescope are then rotated through 180° , so that the wire which was first before rotation is now the last. The time required for a zenith star to cross the wires being four minutes, there is plenty of time to effect the rotation and for the telescope to come to rest before the star again crosses the wire. This it does, but of course in the opposite direction and on the opposite side of the zenith on the plate. The zenith then is the point midway between the two trails made by the star; and if several stars are allowed to register their trails the zenith points derived from them should agree within the limits of errors of measurement. At the same time if the declination of the star is known, half the distance between the trails of the star added to or subtracted from, as the case

may be, the apparent declination will give the latitude. The discussion of this is reserved for another section.

The following is an example, chosen at hazard, of the method employed :—

	Star.	Corrected Reading. mm.	Zenith Point.
L. 7, Feb. 11	2 <i>a</i>	60·6393	41·8202
	<i>b</i>	23·0010	41·8237
	3 <i>a</i>	26·3290	
	<i>b</i>	57·3184	41·8194
	5 <i>a</i>	49·7550	
	<i>b</i>	33·8837	39·5275
	1 <i>a</i>	33·4036	
	<i>b</i>	45·6513	39·5305
	4 <i>a</i>	33·2343	
	<i>b</i>	45·8267	

No corrections are necessary except those for errors of the micrometer. The first three stars registered their trails over the wire called III, the last two over wire I ; and the maximum difference in right ascension of the stars on the same wire is 16·2 minutes. The thermometers both inside and outside the dome and on the instrument showed, as is usual, no change of temperature during this interval. The two stars 2 and 3, having very nearly the same right ascension, form a pair, and the zenith points deduced from them would be the same were there no errors of measurement. Twenty-four determinations of the zenith point from two or more stars, similar to the two examples given here, have been made ; but the differences of the zenith points determined by the two stars of the pair 2 and 3 above and another such pair, the probable error of the determination of a zenith point arising from error of measurement alone, is found to be $\pm 0''\cdot223$; and from the stars not forming pairs, such as 1 and 4 above, the probable error due to error of material is not sufficient to make it possible to deduce the probable errors of the determination of the zenith point arising from accidental errors of measurement and from the error of floatation. All that can be stated at present is that the mean difference in the reading for the zenith point is $0''\cdot30$ for a pair of stars, and $0''\cdot37$ for stars not forming pairs : the former figure rests on ten determinations, and arises from error of measurement alone ; the latter is the mean of twenty, and is due to the errors of measurement and of floatation combined.

Latitude.—Owing to continued bad weather it has not been possible to secure a series of observations of Talcott stars, but the measurements of trails of zenith stars taken to test the stability of the float have been reduced and the latitude derived from them. This method of finding the latitude consists simply in the observation of the zenith distance of single stars. A star registers

its trail across a wire two minutes before its meridian passage : the float and telescope which is pointed to the zenith are then rotated through 180° in azimuth, and the star crosses the same wire as before two minutes after meridian passage ; but the two trails made by the star are on opposite sides of and at equal distances from the projection of the zenith on the plate. From half the measured distance between the trails the meridional zenith distance of the star is found by applying the following corrections :—

1. Correction for curvature of star's path or reduction of the meridian given by the formula

$$c = \frac{15^2}{2} \sin 1'' \tan \delta C^2$$

where C is the collimation constant expressed in equatorial seconds. This correction is a constant for each star, and is always to be added to the declination.

2. Correction for projection of the celestial sphere on to the photographic plate. The sign of this correction is the same as that of the star's zenith distance, and its magnitude is found from the expression

$$1''.52 x^3 10^{-5}$$

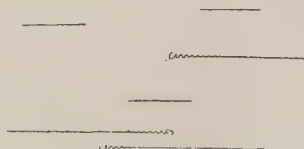
where x is the distance in millimetres from the centre of the plate. When the distance x' is not measured along a line passing through the centre of the plate, but along a line distant y millimetres from the centre, the correction is

$$\delta x' = 1''.52 x' (x'^2 + y^2) 10^{-5}$$

This correction is most easily applied by reading off its value from a large scale chart showing the values of $\delta x'$ for a given value of x' , y being an instrumental constant.

3. The last correction is that for refraction. This is small, as only stars culminating within $1\frac{1}{2}^\circ$ of the zenith can be used ; but it undergoes small variations with the meteorological conditions unless the zenith distance does not exceed $20'$.

Of these three corrections the first two are constants for a given star, and are to be applied once and for all to its mean declination. The only day corrections are the refraction and the reduction to date. The latter has been carried out by means of Finlay's Star Tables.



The appearance of a latitude plate is shown above ; the oscillations are caused by the rotation of the float and telescope.

Twenty-six stars were chosen, so that the sums of the north and of the south zenith distances were very nearly equal. The mean latitude from all the stars would in this way be made very nearly independent of the scale value, but cloudy weather unfortunately prevented these observations from being completely carried out on even one night. The following results, however, are given in order to show what may be expected from this method of observing with the instrument.

In the following table the declinations are given of those stars of which observations have been secured. In the second column N. denotes Newcomb's *Catalogue of Fundamental Stars*, 1900; P. the Poulkova Catalogue of 1855, published in vol. viii. of the *Poulkova Observations*; and A.G.C. the Harvard Zones of the *Astronomische Gesellschaft Catalog.* The declinations of the Poulkova Catalogue have been reduced to Newcomb's system by applying the corrections given in his Catalogue, p. 234, and the Harvard declinations by means of those given in the introduction of the Catalogue of that observatory.

Group and Number.	Catalogue.	Approx. R.A.	Declination 1901.	Proper Motion o"/cent.	Approx. z. d.
		h m 1901.			
L. 1. 1	N. 182	2 47.2	52° 21' 26".95	— 3	— 8.9
2	A.G.C. 1353	53.7	51 57 30.83		+ 15.0
3	N. 190	57.6	53 7 8.24	— 4	— 54.6
4	A.G.C. 1388	3 0.9	51 49 56.74		+ 22.6
5	A.G.C. 1405	4.5	51 47 20.28		+ 25.2
L. 2. 1	P. 694	4 32.0	52 52 55.96	— 19	— 40.3
2	P. 693	32.0	53 16 41.48	— 91	— 64.1
3	A.G.C. 1932	37.1	52 9 12.56		+ 3.4
4	A.G.C. 1996	45.2	52 40 27.41		— 27.9
5	P. 770	58.8	51 27 59.86	— 166	+ 44.7
6	A.G.C. 2116	5 6.7	53 5 47.12		— 53.1
∞	P. 739	4 49.3	53 35 38.05	+ 12	— 83.0
L. 5	N. 520	8 1.0	51 47 32.17	— 3	+ 25.4
L. 6	N. 546	8 32.0	53 3 31.78	— 22	— 50.6
L. 7. 1	P. 1448	9 1.9	52 0 16.56	— 35	+ 12.7
2	A.G.C. 3354	13.5	52 52 5.58		— 39.1
3	P. 1476	13.8	51 40 48.22	+ 137	+ 32.2
4	A.G.C. 3380	18.1	51 59 55.34		+ 13.1
5	P. 1509	28.0	52 29 30.71	— 37	— 16.5

From observations of these stars seventy-one determinations of the latitude have been derived. All the stars in each of the groups L. 1, L. 2, and L. 7 were taken on one plate. Since the exposures are made for one minute, while a star is crossing a wire, the total exposure of a plate to the sky is about 10 minutes.

When the Moon is nearly full and very bright this causes a slight fogging of the plate, but not sufficient to seriously impair the definition of the faintest stars used; that is, of magnitude 6.6 on the scale of the Draper Catalogue. The sums of the zenith distances in the groups L. 1 and L. 7 are $-0^{\circ}.7$ and $+2^{\circ}.4$ respectively, and the mean latitudes derived from them are therefore nearly independent of scale value. The latitude given by the star L. 2 α has been found by measuring the distance of its trail from the zenith point given by the trails of the stars 3 and 5. The agreement of the values thus found shows that this procedure is capable of giving accurate results. In the next table the seconds of the latitude are given under the number of the star, together with the approximate zenith distance.

TABLE I.

	L. 2.	1	2	3	4	5	6	α	L. 5.	L. 6.
		$-40^{\circ}.3$.	$-64^{\circ}.1$.	$+3^{\circ}.4$.	$-29^{\circ}.9$.	$+44^{\circ}.7$.	$-53^{\circ}.1$.	$-83^{\circ}.0$.	$+25^{\circ}.4$.	$-50^{\circ}.6$.
Feb. 3	...	...	...	...	...	...	...	...	$51^{\circ}.05W$.	"
6	$50^{\circ}.40W$.	$51^{\circ}.40W$.	...	...	$52^{\circ}.14E$.	...	$52^{\circ}.57E$.	...	...	...
10	$50^{\circ}.42E$.	$50^{\circ}.93E$.	$51^{\circ}.04W$.	$52^{\circ}.15E$.	...	...	...	...	...	...
11	$50^{\circ}.69W$.	$51^{\circ}.72W$.	$50^{\circ}.60E$.	$51^{\circ}.89W$.	$52^{\circ}.51E$.	...	$52^{\circ}.16E$.	$51^{\circ}.33E$.	$51^{\circ}.88E$.	...
12	$49^{\circ}.84E$.	$50^{\circ}.89E$.	$50^{\circ}.90W$.	$52^{\circ}.62E$.	$51^{\circ}.97W$.	$50^{\circ}.83E$.	$52^{\circ}.34W$.	...	...	...
13	$50^{\circ}.48W$.	$51^{\circ}.50W$.	$50^{\circ}.77E$.	$52^{\circ}.11W$.	$52^{\circ}.90E$.	$51^{\circ}.21W$.	$52^{\circ}.91E$.	$51^{\circ}.56W$.	$51^{\circ}.98W$.	...
Mean	$50^{\circ}.37$	$51^{\circ}.29$	$50^{\circ}.83$	$52^{\circ}.19$	$52^{\circ}.38$	$51^{\circ}.02$	$52^{\circ}.50$	$51^{\circ}.31$	$51^{\circ}.93$	

TABLE II.

	L. 1.	1	2	3	4	5	Mean
		$-8^{\circ}.9$.	$+15^{\circ}.0$.	$-54^{\circ}.6$.	$+22^{\circ}.6$.	$+25^{\circ}.2$.	
Jan. 22	$51^{\circ}.52W$.	$52^{\circ}.04E$.	$51^{\circ}.25W$.	$51^{\circ}.93E$.	...	$51^{\circ}.90$	
31	$51^{\circ}.03E$.	$52^{\circ}.35W$.	$51^{\circ}.49E$.	$51^{\circ}.64W$.	$52^{\circ}.78E$.	$51^{\circ}.88$	
Feb. 1	...	$51^{\circ}.80E$.	$51^{\circ}.51W$.	$51^{\circ}.74E$.	$52^{\circ}.39W$.	$51^{\circ}.75$	
Mean	$51^{\circ}.28$	$52^{\circ}.06$	$51^{\circ}.42$	$51^{\circ}.77$	$52^{\circ}.59$	$51^{\circ}.85$	

	L. 7.	1	2	3	4	5	Mean.
		$+12^{\circ}.7$.	$-39^{\circ}.1$.	$+32^{\circ}.2$.	$+13^{\circ}.1$.	$-16^{\circ}.5$.	
Feb. 2	$51^{\circ}.75W$.	$50^{\circ}.71E$.	$50^{\circ}.52E$.	$50^{\circ}.49W$.	$50^{\circ}.64E$.	$50^{\circ}.82$	
3	$52^{\circ}.06E$.	$51^{\circ}.22W$.	$51^{\circ}.38W$.	$51^{\circ}.05E$.	$51^{\circ}.36W$.	$51^{\circ}.41$	
5	$51^{\circ}.52W$.	$50^{\circ}.92E$.	$50^{\circ}.97E$.	$50^{\circ}.80W$.	$50^{\circ}.75E$.	$50^{\circ}.99$	
11	$51^{\circ}.56W$.	$50^{\circ}.90E$.	$50^{\circ}.42E$.	$50^{\circ}.58W$.	$51^{\circ}.37E$.	$50^{\circ}.97$	
13	$51^{\circ}.95E$.	$51^{\circ}.13W$.	$50^{\circ}.84W$.	$50^{\circ}.97E$.	$51^{\circ}.48W$.	$51^{\circ}.27$	
Mean	$51^{\circ}.77$	$50^{\circ}.98$	$50^{\circ}.83$	$50^{\circ}.78$	$51^{\circ}.12$	$51^{\circ}.09$	

It will be seen from this table that in no case do the values of the latitude determined from the same star differ by as much as $1''$.0, even for such considerable zenith distances as 1 degree.

The probable error of one determination from all the values above is $\pm 0''\cdot200$, but it will be noticed that there is a large systematic difference between the values found for circle east and circle west, which considerably increases the probable error. Thus the differences for the five stars in L. 7 in the sense E.—W. are

1	$+0''\cdot40$	4	$+0''\cdot45$
2	$-0''\cdot34$	5	$-0''\cdot50$
3	$-0''\cdot47$		

If a correction of $\pm 0''\cdot20$ is applied to the values of the latitude in this group according as the circle is west or east, the probable error of a single determination is reduced to $\pm 0''\cdot115$, which is smaller than the value found by a skilful observer with a visual telescope, viz. $\pm 0''\cdot125$. If, now, the differences from the daily mean are found for each of the five stars, and the mean difference for each star is applied as a correction to every determination of the latitude by that star, the following values are found :—

L. 7.	1	2	3	4	5	Mean.
Feb. 2	$51''\cdot27$	$51''\cdot02$	$50''\cdot98$	$51''\cdot00$	$50''\cdot81$	$51''\cdot02$
3	$51''\cdot18$	$51''\cdot13$	$51''\cdot44$	$51''\cdot16$	$51''\cdot13$	$51''\cdot21$
5	$51''\cdot04$	$51''\cdot23$	$51''\cdot43$	$51''\cdot31$	$50''\cdot92$	$51''\cdot19$
11	$51''\cdot08$	$51''\cdot21$	$50''\cdot88$	$51''\cdot09$	$51''\cdot14$	$51''\cdot17$
13	$51''\cdot07$	$51''\cdot04$	$50''\cdot90$	$51''\cdot08$	$51''\cdot25$	$51''\cdot07$

An explanation of the difference E.—W. has yet to be found ; but its existence seems to be so conclusively shown that the above may be taken as an example of the result to be expected from the instrument.

Note accompanying Photographs of the Spectrum of Nova Persei.
By Frank McClean, LL.D., F.R.S.

The observations made by me of the spectrum of *Nova Persei* at present extend from February 25 to March 6. On the 23rd and 24th the star was not visible. On the 25th some glimpses of the spectrum were obtained through passing gaps in the clouds. The star was then considerably brighter than *a Persei*. The general character of its spectrum did not subsequently change, although apparently the red hydrogen line became brighter.

From February 27 till March 3 photographs of the spectrum were obtained by me on each night with the 12-inch object glass prism, and again on March 5 and 6.

The two enlarged spectra exhibited were taken on February 27 and March 3. In extent, they reach from (H ζ) to the position of the (*b*) line of magnesium. Comparison spectra of *Sirius* and β *Crucis* are mounted on the same plate. The hydrogen series are at once identified in the spectrum of *Nova*. They appear both as ill-defined absorption lines and as broad bright bands, displaced towards the red, but joining up to the dark lines.

The helium series of lines do not appear with any certainty either as bright or as dark lines or bands.

The calcium (K) line is present, and there are other absorption bands which appear to be partly due to calcium and titanium. There are also other indistinct bright bands which have not been identified.

On the second photograph, taken on March 3, when the star had diminished somewhat in brightness, the spectrum remains the same, except that some of the dark bands have become more prominent.

The comparison with the spectrum of *Sirius* shows a certain correspondence between the grouping of the absorption lines in that spectrum and the dark bands in the spectrum of *Nova*. The correspondence is far from clear, but it is sufficient to suggest the idea that *Nova* is a Sirian star with additional bright bands due in the main to hydrogen. The displacement of the bright hydrogen bands to the less refrangible side of the absorption lines and their great width is attributed to differences of velocity in the line of sight between two or more sources of light. It should be observed, however, that in the case of *Nova Aurigæ* the bright bands were displaced in the same direction. No definite observations on this point appear to have been made with regard to *Nova Cygni* or *Nova Coronæ*. If the displacement is to be accounted for by differences of velocity, it should be as often one way as the other.

I hope to obtain some further photographs of the spectrum of *Nova* before it disappears, and will then place the full series before the Society.

1901 March 8.

Notes on the Spectrum of Nova Persei observed at the Stonyhurst College Observatory.

By the Rev. Walter Sidgreaves, S.J.

On the night of February 28 the cloud-cover, which had been persistent since the 20th, suddenly thinned at 10.15 P.M. to a hazy clearness. The *Nova* appeared rather brighter than *a Persei*. The spectrum was observed with the direct vision spectroscope on the 15-inch O.G. equatorial, and two photographs were obtained, one with this spectroscope, the other with a 4-inch

objective prism of $22\frac{1}{2}^\circ$ refractive angle, by Mr. Thorp of Manchester, mounted on the Cooke finder of nearly 4 inches aperture.

The following notes refer mostly to the latter photograph, and to another taken with the same prism on March 3, when the star was rather fainter than *Algol*, but the sky much clearer between passing clouds. The plates were Mawson Stellar Rapid, and the one used with the direct compound prism an Edwards Isochromatic.

1. *The continuous spectrum* of the *Nova* is remarkable for its strength in the ultra-violet beyond the hydrogen series. The relative intensity here is such that if the rest of the spectrum were in accord with the sensibility curve of the plate, the blue region should be represented by a silver deposit darker than the darkest bands between $H\beta$ and $H\gamma$. This of itself would suggest that the dark bands of the negative between the hydrogen lines are not radiation lines, and that the spaces between them are absorption lines. But there is conclusive evidence on the plates that this is not the true interpretation of the spectrum. The continuity of the spectrum can be traced all along the photographs; and the region near $H\beta$ on the violet side removes all doubt: this is undoubtedly continuous spectrum, and the silver density is quite in keeping with the paler spaces up to the $H\theta$, where it ceases to fade as rapidly as in other photographs of both white and yellow stars.

2. *The hydrogen lines* are very brilliant and very broad. The first three were easily seen on both dates without the aid of a cylindrical lens, $H\alpha$ attracting the eye immediately. On the photographic plates $H\beta$ is very intense, and the intensity of the others decreases in succession up to $H\zeta$ inclusive. $H\eta$ is nearly as strong as $H\zeta$, while $H\theta$ and $H\iota$ are much weaker and equal. $H\iota$ is the last of the series, although the continuous spectrum is very distinct considerably beyond this position. There are, however, two exceedingly feeble bright bands near, but the spaces between are nearer the positions of $H\kappa$ and $H\lambda$.

$H\beta$, $H\gamma$, $H\delta$, and $H\eta$ have certainly absorption companions on their violet sides. They are narrow compared with the bright lines. The apparent absorptions near the other lines may be mere contrast effects, but on the enlarged positive they look like decided absorptions.

The first four hydrogen bright lines β , γ , δ , and ϵ are sharper on their violet sides, and shade off towards the red side. $H\eta$ has the same appearance; but I think this line must be superposed on another bright band: it is out of proportion in breadth if the shading wing be considered part of the same line.

$H\beta$, $H\delta$, and $H\zeta$ are each divided by a fine absorption line nearly central, and $H\gamma$ is probably divided in the same way.

The other bright lines of the spectrum are broad like the hydrogen lines. There are three very prominent ones besides narrower lines between D and F on the Isochromatic plate; and

on the Mawson plate there are four between $H\beta$ and $H\gamma$, and four also between $H\gamma$ and $H\delta$, one of which adjoins $H\delta$; and one, the calcium line K, between $H\epsilon$ and $H\zeta$.

The *Isochromatic plate* was exposed under rather worse atmospheric condition: the haze was thickening, and the star low down. The photograph is weak and the definition not good. But the positions of 14 lines were found to agree closely with those of *Nova Aurigæ* in 1892 February. The λ curve for the objective prism has not yet been plotted.

On the New Star in Perseus. By A. Stanley Williams.

A photograph of the region including *Nova Persei* was obtained here on the night of February 20 with a 4·4-inch Grubb portrait lens, and an exposure of 47 minutes (1901 February 20, 10^h 40^m to 11^h 27^m Greenwich mean time). There is no certain trace of the *Nova* visible upon this plate, which shows distinctly stars down to about the 12th magnitude, so that it must have been fainter than this at the time the photograph was taken. When discovered by Dr. Anderson on February 21 at 14^h 40^m, the star had already attained a magnitude of 2·7, so that in an interval of not more, and probably less, than 28 hours a rise of about 9½ magnitudes at least must have occurred.

Similar photographs were obtained on 1901 January 15 and 25 and February 11, on none of which is any certain trace of the star to be seen. There are two or three very minute stars visible near its place, but none of them appear to occupy exactly the same position.

The following eye-estimates of the brightness of the *Nova* were made by the writer.

1901 February 25, 11½^h, *Nova* about midway between *Capella* and *a Persei*, but sky never perfectly clear.

Feb. 26	11½ ^h	3 steps brighter than <i>a Persei</i>
Feb. 28	10	3 steps brighter than <i>a Persei</i>
Mar. 1	9½	5 steps fainter than <i>a Persei</i>
Mar. 1	12	7 steps fainter than <i>a Persei</i>
Mar. 3	7 10 ^m	6 steps below <i>a Persei</i> , 2 steps below β <i>Persei</i> , 10 steps above δ <i>Persei</i>

In all these observations there was a bright Moon. On March 1 the *Nova* was also thought to be about equal to *Algol*, but comparison was unsatisfactory, owing to the difference in the colours of the two stars. Adopting the H.P. magnitudes of the comparison stars, and assuming the value of a step to be 0·1 mag-

nitude, the following will be the provisional brightness of the new star on the H.P. scale :—

1901 Feb. 25	11 $\frac{1}{2}$ ^h	mag. = 1.06
„ 26	11 $\frac{1}{2}$	„ = 1.64
„ 28	10	„ = 1.64
Mar. 1	9 $\frac{1}{2}$	„ = 2.44
„ 1	12	„ = 2.64
„ 3	7 10 ^m	„ = 2.41

Judging from its powers of penetrating through cloud, the *Nova* was thought to be comparable with *Capella* on February 23. Its colour also appeared to be the same. With a 2 $\frac{3}{4}$ -inch refractor the colour was noted as intense bright white on February 25, as yellowish on February 26, and as white—with perhaps a tinge of yellow—on March 3. With the naked eye, aided by spectacles, the colour has always been distinctly yellowish.

Hove : 1901 March 4.

A First Note on the Nova in Perseus. By Professor K. D. Naegamvala, M.A.

On the afternoon of February 25 the following telegram was received from Captain Molesworth, R.E., stationed at Trincomali, in Ceylon :—

“First magnitude star, *Perseus*, right ascension 3.24, declination north 44. Kindly reply whether *Nova* and examine spectrum.”

The weather here has been very unfavourable of late, the sky being often overcast, and fleecy clouds present as a rule throughout. A single glance the same evening, however, left no doubt that the star was a *Nova*, fully as bright as β *Geminorum*. It was photographed with a 4-inch portrait lens with one minute's exposure, and a preliminary examination with a Vogel eyepiece spectroscope revealed a bright-lined spectrum. Two spectrograms were also taken the same evening with a prismatic camera composed of a Cooke triple objective of 93-inch focus and a prism of 45°. Owing to an unfortunate maladjustment of the prism the plates came out blank on development.

The next evening (February 26), and on the two following, the *Nova* was carefully observed with Vogel and McClean spectroscopes of varying dispersion applied to the 16-inch guiding

telescope of the photographic reflector of the observatory, and the following is the summary of the observations. To avoid any bias I purposely refrained from referring to the previous observations of *Nova Aurigæ*, which were not consulted till yesterday.

There is a bright band in red (C), one in yellow (D_3), four in green, and two in blue.

There are four maxima at least in green. The maximum of brightness in the spectrum is in the extreme green, *i.e.* towards the violet.

The last band in blue is broadest, the last of four in green ($H\gamma$) comes next, then the first (of the two bands) in blue ($H\delta$), then C.

The last band in green ($H\gamma$) is brightest, then the last in blue ($H\epsilon$?), then in red ($H\beta$), and then the first in blue ($H\delta$).

Black bands on the violet or more refrangible sides of all the above bright bands except to " $H\epsilon$?" This absence of a black band is most probably due to the great falling off of the continuous spectrum in this region. The black band of $H\delta$ was intensest; next came that of $H\gamma$, and then of $H\beta$. The bright D_3 has also a black companion.

There is a faint broad bright band in the middle of the red portion of the spectrum, resolvable by glimpses into lines. Besides this there is also a very fine bright line in red nearer to $H\beta$, with a companion dark line.

The visible magnitude of the *Nova* on February 26 was about equal to that of β *Geminorum*, on the 27th less than β but greater than α *Geminorum*, while on the 28th it was certainly not greater than α *Geminorum*.

Four spectrograms have been secured during the last three evenings. These show at least sixteen maxima and minima of bright radiations between the region $H\beta$ and K(Ca), each accompanied by a dark companion. I defer for the present their discussion, but a casual comparison with the spectra of *Sirius* and *Capella* taken with the same instrument incontestably testifies to large shifting of the bright bands towards the less refrangible side of the spectrum; the black companions are also in all probability shifted in the opposite direction.

Maharaja Takhtasingji Observatory, Poona:
1901 March 1.

Positions of Nova Persei and 159 Stars within 25' distance from it. From a Photograph taken at the University Observatory, Oxford. By F. A. Bellamy, F.R. Met. Soc.

After the receipt of the telegram announcing the discovery of the new star in *Perseus* the weather in Oxford was unfavourable, but on February 25, though very cloudy, there were rifts in the clouds, during which I saw *Nova* at its full brilliancy, and though the star was invisible to the eye most of the time the exposures were made, I was able to secure two plates with seven exposures, between 10^s and 13^m exposure, the star being visible all the time in the $12\frac{1}{4}$ -inch refractor, used as a guiding telescope for astrographic work, sometimes as faint as a third or fourth magnitude star.

The plates taken were—

1727. Exposures, 10^s , 2^m , 2^m , 15^s between Oxf. Sid. T. $5^h 13^m 7^s$ and $5^h 21^m 17^s$.

1728. Exposures, 220^s , 8^m , $13\frac{1}{4}^m$ between Oxf. Sid. T. $6^h 20^m 7^s$ and $6^h 56^m 42^s$.

On the second plate a trail for ten minutes was also given.

Plate 1728 was measured by Mr. E. A. Gray, with the glass scale micrometer, in one of the instruments used for the astrographic catalogue, first in the direct, then in the reversed position, so as to eliminate personality, and all three exposures were measured for the stars used in determining the plate constants and the *Nova*; but for the other stars given in the subjoined catalogue only the second and third exposures were measured, the majority of the faint stars not being visible with the short exposure, owing to cloud.

The places of all stars which could be found in the Bonn A.G. Catalogue ($+40^\circ$ to $+50^\circ$) within the area covered by the plate were brought to the epoch 1900.0, and standard coordinates (ξ and η), with reference to the adopted plate centre R.A. $3^h 25^m +44^\circ 0'$, were computed by means of the formulæ given in *Monthly Notices*, liv. 11.*

The Oxford measures x , y (reckoned from the corner of the réseau, not the centre) were compared with these coordinates, equations formed and solved in the usual way, and the constants were found to be—

a	b	c	d	e	f	
		R.I.				R.I.
$+00031 + 00539 - 14'3491$			$-00528 + 00031 - 14'3797$			

where $\xi = x(1+a) + by + c$, $\eta = dx + (1+e)y + f$.

In Table I. are collected these computed R.A.'s and Dec.'s, the corrections deduced from this plate, and the Oxford standard coordinates ξ' and η' . This information may be useful to others.

* Tables for simplifying the use of these formulæ for 0° to 75° have been prepared and will soon be printed.

TABLE I.

Bonn A.G.C.	Mag.	R.A. 1900'0.			Oxf- Bonn.	N. Dec. 1900'0.			Oxf- Bonn.	$\xi' = \xi + 13.$	$\eta' = \eta + 13.$
		h	m	s		°	'	"		R.L.	R.L.
2883	7.9	3	20	8.46	-0.04	43	18	19.0	+0.7	2.3894	4.7425
2892	9.0	3	20	32.68	-0.09	43	22	27.4	+1.8	3.2801	5.5618
2895	8.6	3	20	54.84	-0.02	43	49	37.7	-1.0	4.1556	10.9769
2898	8.3	3	21	13.98	+0.15	44	2	31.5	+0.4	4.8816	13.5527
2899	9.0	3	21	14.69	+0.04	43	59	31.6	-2.2	4.8964	12.9441
2906	7.2	3	21	29.67	+0.12	44	1	43.7	+0.3	5.4429	13.3870
2907	8.9	3	21	34.92	0.00	43	38	39.2	+0.3	5.5797	8.7697
2911	7.7	3	21	46.67	0.00	43	24	21.3	-0.4	5.9765	5.9035
2913	8.2	3	21	52.65	+0.01	44	18	3.0	-0.3	6.2959	16.6410
2919	8.4	3	22	22.44	+0.08	44	42	9.6	-0.7	7.4030	21.4528
2944	8.7	3	23	44.27	0.00	44	29	19.3	-0.1	10.2986	18.8695
2948	9.0	3	24	3.23	-0.06	43	38	29.4	+0.7	10.9438	8.7031
2953	9.0	3	24	17.74	-0.15	43	51	59.1	-1.0	11.4713	11.3953
2956	8.7	3	24	29.11	-0.04	44	18	43.0	+0.5	11.8935	16.7457
2964	8.5	3	24	47.37	+0.03	44	11	29.7	+0.7	12.5482	15.3013
2968	8.9	3	25	1.70	-0.03	44	3	34.5	+0.2	13.0599	13.7156
2970	9.2	3	25	12.46	-0.03	44	28	18.5	0.0	13.4437	18.6618
2971	9.0	3	25	12.72	+0.12	44	37	16.6	+0.1	13.4569	20.4556
2972	8.8	3	25	14.39	+0.55	43	19	56.2	-1.3	13.5434	4.9831
2973	7.6	3	25	24.80	-0.09	44	29	58.7	+0.2	13.8813	18.9969
2979	6.5	3	25	47.09	+0.04	44	30	56.4	-0.1	14.6804	19.1899
2982	8.9	3	25	58.20	-0.09	43	53	43.4	+0.7	15.0939	11.7500
2983	8.9	3	26	4.87	+0.33	43	25	16.5	+0.4	15.3680	6.0598
2986	8.9	3	26	13.77	-0.02	43	15	45.8	-0.4	15.6855	4.1558
2996	9.1	3	27	3.65	-0.16	43	30	45.2	+0.8	17.4781	7.1669
3004	9.1	3	27	24.91	-0.01	43	24	19.9	-0.2	18.2637	5.8846
3008	9.0	3	27	45.33	-0.15	44	14	52.7	-0.4	18.9162	15.9991
3009	6.9	3	27	50.20	-0.14	44	28	2.0	-1.5	19.0686	18.6283
3016	8.5	3	28	31.81	-0.18	43	30	46.1	+1.1	20.6743	7.1978
3021	8.9	3	28	51.01	+0.04	42	57	22.2	-0.2	21.4566	0.5203
3034	8.9	3	29	56.53	-0.09	43	44	41.3	+0.4	23.7084	10.0187

When two exposures only are used (as in the case of 159 stars in the annexed catalogue) the constants c and f become

$$\begin{array}{c} c \\ \text{R.L.} \\ -14.3473 \end{array}$$

$$\begin{array}{c} f \\ \text{R.L.} \\ -14.4795 \end{array}$$

a, b, d, e remaining sensibly unchanged.

These mean measures were corrected for the plate constants, the quantities being carried to the fourth decimal place throughout, and were converted into differences of R.A. and Dec. A catalogue of these stars is given at the end of this paper.

Owing to the great diameter of the image of *Nova* on the plate ($35''$ to $50''$) special care was taken to render the mean measures in x and y as exact as possible. Each image was bisected and two contact measures made in both positions of the plate by Professor Turner, H. F. Mullis, B. Gray, E. A. Gray, and myself. The mean of the whole series of 45 measures each in x and y was taken. The resulting means for 1900.0 are

$$\begin{array}{cc} \xi & \eta' \\ \text{R.L.} & \text{R.L.} \\ 12^{\text{h}} 9956 & 9^{\text{h}} 1883 \end{array}$$

which, corrected for constants already mentioned for the mean of three exposures, give

$$\text{R.A. } 3^{\text{h}} 24^{\text{m}} 24^{\text{s}}.12 \quad \text{Dec. } +43^{\circ} 33' 39''.51$$

There appears not to be any star brighter than about the 12th mag., or nearer to the *Nova* than $4'$, unless the brilliancy of the star, approximately equal to *Aldebaran*, obliterated some faint stars within $30''$ of *Nova*. Photographs when *Nova* is below the 6th mag. would soon decide this point. It may be mentioned that photographs taken on February 27 and March 5 do not show other stars nearer.

Some estimations of magnitude have been made, and the following notes are extracted from the note-book.

Feb. 25. 8^{h} . To the eye the colour was white, with possibly a tinge of yellow. In the $12\frac{1}{4}$ -inch refractor the colour appeared as emerald or young grass green. Mag. about 1.3.

Feb. 27. $7\frac{1}{2}^{\text{h}}$. *Nova* = β *Tauri*, also equal to the brightest star in *Orion's* belt, nearly $\frac{1}{2}$ mag. brighter than α *Persei*.

Feb. 28. 10^{h} . *Nova* certainly brighter than α *Persei*.

Mar. 1. 7^{h} . *Nova* = α *Persei* and β *Aurigæ*, slightly fainter than β *Tauri*; colour slightly orange; had not seen this tinge on other nights. Plate taken in a small camera to locate the position of *Nova* in the constellations *Perseus*.

Mar. 5. 7^{h} *Nova* = δ *Cassiopeiæ*.

Mar. 6. 8^{h} *Nova* = ϵ *Persei*, or 0.1 or 0.2 fainter; orange.

Mar. 7. 12^{h} *Nova* = γ and δ *Persei*, less orange in colour.

I should like to express my thanks to Mr. H. F. Mullis, Mr. B. Gray, and Mr. E. A. Gray for assistance they have given beyond the usual hours at the observatory, thus making it possible to get these results completed in so short a time.

The stars in Table II. are situated within about five réseau intervals of the *Nova*, and may serve as points of reference should the star decrease to a fainter magnitude than the tenth. On account of the cloud it is not easy to decide what is the limit of magnitude of these 159 stars; probably, judging from the

number of stars on the whole plate (over 1200), stars of less than the 12th mag. are on the plate.

Col. 1. The catalogue number : those with * are independent measures of two exposures of Bonn stars.

2. The measured diameter of the star's image, the quantity given being the mean of four separate measures ; unit '001 of a réseau interval.

3-4. The standard coordinates, ξ' , η' , for 1900'0 ; i.e. from the (S.W.) corner of the plate, with centre $3^h 25^m + 44^\circ$.

5-6. The deduced R.A.'s and Dec.'s for 1900'0.

TABLE II.

Ref. No.	Oxford Measured Mag.	ξ'	η'	Deduced			N. Dec. 1900.
		1900'0	1900'0.	R.A. 1900'0.			
		R.L.	R.L.	h	m	s	
1	7	6'7173	5'2152	3	22	7'22	43° 20' 56''6
2	6	6'7805	6'8797	22	8	56	29 16'0
3	7	6'8289	2'6972	22	10	88	8 21'6
4	5	6'8762	2'6530	22	12	19	8 8'5
5	12	7'0318	11'2263	22	14	49	51 0'5
6	10	7'1473	8'9722	22	18	20	39 44'6
7	10	7'1594	4'4411	22	19	55	17 5'4
8	6	7'1752	5'1646	22	19	82	20 42'5
9	10	7'2800	2'6128	22	23	26	7 57'4
10	8	7'4228	9'0376	22	25	80	40 4'8
11	11	7'4178	4'7023	22	26	59	18 24'4
12	6	7'7115	2'7717	22	35	05	8 46'0
13	9	7'7523	4'1085	22	35	90	15 27'1
14	7	7'8908	12'1423	22	38	12	55 37'2
15	7	7'8472	4'6643	22	38	40	18 14'0
16	10	7'9722	10'1806	22	40	77	45 48'9
17	7	8'0104	6'5116	22	42	53	27 28'4
18	9	7'9932	2'8825	22	42	75	9 19'8
19	7	8'0550	6'6181	22	43	74	28 0'5
20	9	8'2079	11'8330	22	46	99	54 5'1
21	12	8'2567	5'8006	22	49	44	23 55'6
22	5	8'3181	11'7280	22	50	06	53 33'8
23	12	8'3504	8'3742	22	51	56	36 47'8
24	7	8'3684	4'1699	22	52	81	15 46'7
25	5	8'3830	3'7626	3	22	53'28	43 13 44'6

Ref. No.	Oxford Measured Mag.	ξ'	η'	Deduced			N. Dec. 1900.
		1900'o.	1900'o.	R.A. 1900'o.			
		R.I.	R.I.	h	m	s	
26	8	8'4671	5'9987	3	22	55'20	43° 24' 55''
27	11	8'6731	9'6113	23	0	27	42 59'5
28	8	8'6678	3'7991	23	1	09	13 56'0
29	9	8'7229	11'4830	23	1	34	52 21'1
30	11	8'7189	9'0150	23	1	64	40 0'7
31	8	8'7840	9'6431	23	3	34	43 9'2
32	12	8'7982	11'0677	23	3	50	50 16'6
33	11	8'9406	11'1344	23	7	43	50 36'9
34	11	9'2346	11'6606	23	15	51	53 15'2
35	6	9'1905	3'0091	23	15	55	10 0'0
36	6	9'2458	3'5278	23	16	99	12 35'6
37	12	9'3510	8'4360	23	19	19	37 8'1
38	9	9'4696	11'5707	23	22	04	52 48'6
39	8	9'4789	5'9639	23	23	06	24 46'7
40	8	9'5351	11'4722	23	23	87	52 19'1
41	10	9'8003	2'6865	23	32	31	8 24'1
42	9	9'8423	10'5063	23	32	51	47 29'8
43	5	9'8394	6'0751	23	32	97	25 20'6
44	7	9'9197	10'2003	23	34	69	45 58'1
45	7	9'9569	12'5492	23	35	45	57 42'8
46	13	9'9266	4'4235	23	35	57	17 5'2
47	7	9'9629	12'9249	23	35	57	59 35'6
48	11	10'0321	5'8032	23	38	31	23 59'2
49	6	10'0384	3'8849	23	38	70	14 23'8
50	7	10'0676	7'5783	23	39	09	32 51'8
51	7	10'0665	7'0465	23	39	12	30 12'2
52	6	10'1167	2'9157	23	40	96	9 33'2
53	10	10'3730	3'4441	23	47	93	12 12'0
54	7	10'4252	4'3225	23	49	27	16 35'6
55	8	10'5363	3'6787	23	52	39	13 22'5
56	8	10'6322	3'1005	23	55	07	10 29'2
57	9	10'6929	5'2312	23	56	55	21 8'4
58	8	10'8065	12'7476	23	59	04	58 43'3
59	10	10'8263	7'4506	24	0	03	32 12'7
60	6	10'9199	12'7604	3	24	2'19	43 58 47'2

Ref. No.	Oxford Mea-sured Mag.	ξ'	η	Deduced			N. Dec. 1900.
		1900'0.	1900'0.	R.A. 1900'0.			
		R.L.	R.L.	h	m	s	
61*	23	10'9444	8'7044	3	24	3'19	43 38 30'5
62	8	10'9546	6'9584	24	3	61	29 46'7
63	11	10'9804	3'3903	24	4	60	11 56'5
64	10	11'0230	8'1445	24	5	41	35 42'6
65	19	11'1991	2'4820	24	10	66	7 24'2
66	4	11'2059	2'5950	24	10	84	7 58'1
67	8	11'2278	3'8169	24	11	35	14 4'6
68*	21	11'4723	11'3945	24	17	62	51 57'9
69	8	11'4663	3'4237	24	17	92	12 6'8
70	8	11'5474	11'6873	24	19	69	53 25'7
71	11	11'6986	5'6089	24	24	19	23 2'4
72	8	11'7661	3'2378	24	26	16	11 11'2
73	8	11'7940	10'0356	24	26	61	43 45 10'4
74	12	11'8456	13'2607	24	27	89	44 1 17'9
75	8	11'9859	12'8550	24	31	81	43 59 16'3
76	11	12'0015	12'3662	24	32	26	56 49'7
77	10	12'0193	11'6728	24	32	78	53 21'6
78	6	12'0584	4'6838	24	34	12	18 25'1
79	10	12'1098	11'2389	24	35	31	51 11'5
80	7	12'2113	12'9048	24	38	07	59 31'3
81	7	12'4278	11'3322	24	44	13	51 39'6
82	18	12'4578	2'5827	24	45	14	7 55'0
83	8	12'5403	12'9355	24	47	22	59 40'6
84	6	12'5770	3'0904	24	48	40	10 27'3
85	6	12'7788	3'4829	24	53	93	12 25'1
86	14	12'7893	11'6964	24	54	15	53 28'9
87	6	12'7890	6'6892	24	54	18	28 26'8
88	10	12'8008	3'7202	24	54	53	13 36'2
89	7	12'8111	10'0030	24	54	77	45 0'9
90	6	12'8862	6'8995	24	56	86	29 29'9
91	8	12'8892	8'0304	24	56	94	35 9'2
92	12	12'9841	7'7705	24	59	56	33 51'2
93	9	12'9968	11'6668	24	59	91	53 20'0
94	14	13'2595	9'4534	25	7	18	42 16'0
95	9	13'3642	2'3603	3	25	9'98	43 6 48'3

Ref. No.	Oxford Measured Mag.	ξ'	η'	Deducted	
		1900'o. R.I.	1900'o. R.I.	R.A. 1900'o. h m s	N. Dec. 1900. ° ' "
96	14	13'3811	4'4926	3 25 10'47	43 17 27'9
97	6	13'3843	4'0044	25 10'55	15 1'4
98*	24	13'5435	4'9816	25 14'94	19 54'5
99	7	13'5778	4'9449	25 15'89	19 43'5
100	6	13'5923	12'4022	25 16'45	57 0'6
101	10	13'6359	10'676	25 17'61	45 20'2
102	11	13'7104	12'5763	25 19'74	57 52'8
103	10	13'9074	6'7923	25 25'01	28 57'6
104	9	13'9659	12'9999	25 26'86	59 59'8
105	6	14'0701	2'5359	25 29'32	43 7 40'8
106	6	14'0610	13'1492	25 29'51	44 0 44'5
107	7	14'0800	2'6106	25 29'60	43 8 3'2
108	20	14'2295	3'2584	25 33'72	11 17'4
109	7	14'2716	5'7370	25 35'00	23 40'8
110	5	14'3264	12'8717	25 36'87	59 21'2
111	8	14'3598	5'3492	25 37'40	43 21 44'5
112	12	14'3856	13'0664	25 38'53	44 0 19'5
113	9	14'4394	4'4720	25 39'55	43 17 21'3
114	15	14'5152	3'0429	25 41'55	10 12'6
115	8	14'5236	3'9149	25 41'83	14 34'1
116	6	14'5929	11'0541	25 44'17	50 15'7
117	8	14'6687	4'1886	25 45'83	15 56'2
118	6	14'7698	3'6915	25 48'57	13 27'0
119	8	14'7985	4'8313	25 49'44	19 8'8
120	12	14'8120	3'5903	25 49'72	12 56'6
121	6	14'8178	6'8969	25 50'11	29 28'4
122	9	14'8286	4'1124	25 50'21	15 33'2
123	12	14'9275	10'8343	25 53'43	49 9'5
124	11	14'9971	2'5778	25 54'72	7 52'8
125	9	14'9949	8'2309	25 55'10	36 8'5
126	9	15'1112	4'3140	25 57'99	16 33'4
127*	23	15'0958	11'7507	25 58'17	53 44'3
128	11	15'1287	8'1836	25 58'79	35 54'2
129	7	15'1304	7'6805	25 58'79	33 23'3
130	7	15'1230	12'0526	3 25 58'95	43 55 14'8

Ref. No.	Oxford Measured Mag.	ξ'	η'	Deduced		
		1900'o. R.L.	1900'o. R.L.	R.A. 1900'o. h m s		
131	6	15'1675	3'2436	3 25 59'45	43° 11' 12''	
132*	15	15'3678	6'0602	26 5'20	25 17'0	
133	6	15'4797	4'4407	26 8'12	17 11'1	
134	10	15'4767	7'2063	26 8'30	31 0'7	
135	6	15'4705	9'6744	26 8'37	43 21'1	
136	8	15'5793	7'6033	26 11'17	32 59'6	
137	14	15'5873	5'6428	26 11'20	23 11'5	
138	6	15'6301	7'9657	26 12'61	34 48'3	
139	11	15'6248	12'4511	26 12'92	57 13'9	
140	8	15'6418	9'6890	26 13'11	43 25'3	
141	11	15'6509	12'9037	26 13'69	59 29'6	
142*	22	15'6853	4'1553	26 13'74	15 45'2	
143	8	15'7943	3'6361	26 16'68	13 9'4	
144	12	15'7959	10'3846	26 17'45	46 53'8	
145	8	15'8216	4'8806	26 17'56	19 22'7	
146	10	15'8024	12'8268	26 17'90	59 6'4	
147	7	15'8594	12'6533	26 19'46	58 14'3	
148	19	15'9696	10'8286	26 22'31	49 6'8	
149	9	16'0421	8'3544	26 24'03	36 44'4	
150	8	16'1822	4'7090	26 27'46	18 30'8	
151	6	16'2940	8'3478	26 30'99	36 42'1	
152	9	16'3105	11'2022	26 31'81	50 58'4	
153	9	16'3634	9'6309	26 33'07	43 6'9	
154	12	16'4251	4'9172	26 34'16	19 32'9	
155	6	16'4982	3'9712	26 36'04	14 46'0	
156	6	16'4896	9'0373	26 36'48	40 8'7	
157	9	16'5915	8'2546	26 39'19	36 13'8	
158	6	16'7032	9'7561	26 42'49	43 44'0	
159	7	16'7079	12'4399	3 26 43'01	43 57 9'1	

Some years ago I was engaged in making estimations of *Nova Aurigæ* when it fell below the ninth to the 13'5 magnitude ; the accurate or even approximate positions of the surrounding stars were not to be found in any catalogue, the faintness of most of the stars used for comparison rendered their observation with the transit circle impossible ; one had thus to resort to the

less accurate and very tedious process of determining their positions by means of a lower power eyepiece furnished with a ring, letter N, or cross-bar micrometer, which would permit observation of faint stars in a dark field. I remember giving many fine nights, spread over some weeks, to approximately fixing the positions of a comparatively small number of stars about the *Nova*, and I likewise spent a good deal of time for the same purpose in the region surrounding the supposed position of Tycho Brahe's *Nova* of 1572, and intended to proceed in a similar way with other regions about "new" stars; but the tediousness of those methods of observation did not seem to justify one, in view of other and more important work, in expending more time over it, so it was never completed.

With modern methods which have rendered such work so easy I could not let pass the opportunity of securing *photographs* of *Nova Persei* and neighbouring stars at the earliest possible moment.

Observations of the New Star in Perseus made at the Radcliffe Observatory, Oxford.

(Communicated by Arthur A. Rambaut, M.A., Sc.D., F.R.S.,
Radcliffe Observer.)

Since the receipt of the telegram announcing its discovery, observations have been made of Dr. Anderson's new star at the Radcliffe Observatory on every evening that the weather permitted.

On February 23 and 24 the sky was almost continuously overcast, and the star was not seen by us until the evening of the 25th. At this time its magnitude appeared to be 0.9.

The observations include transit-circle determinations of the position of the star on four afternoons, a spectroscopic examination of the light on two evenings, measures of its brightness made with a wedge photometer, and eye-estimates of its brightness as compared with several of the brighter stars.

The transit-circle observations and photometric measures will be published in due time when they have been more fully discussed. The present notice is chiefly concerned with the eye-estimates of magnitude.

In making these comparisons the magnitudes of the Harvard Photometry have been adopted, and the observers have estimated the difference between the *Nova* and each comparison star in tenths of a magnitude. In the results given below no correction has been applied for the atmospheric absorption of light, but as, for the most part, the comparison stars have been taken at various altitudes both above and below the *Nova*, the effect of the absorption

would tend to be eliminated in the mean, and the results of the separate comparisons made on the same occasion show that the means may be relied on to within two or three tenths of a magnitude. On only one occasion was the correction for absorption applied. That was in the comparison made by A.A.R. with Rigel on February 26. At the time of the comparison this star was at a zenith distance of $69^{\circ} 4'$, and in this position the absorption of light would amount to nearly half a magnitude. When the correction for absorption was applied, however, this comparison agreed closely with the others.

The colour of the star has undergone a remarkable change during the short time it has been under observation. Whereas at the time of its discovery, and even up to February 25, when we first saw it, the colour was noted as being bluish white, it has been becoming notably redder from night to night. This change in the colour of the star makes eye-comparisons with the whiter stars a little difficult, and may be to some extent responsible for the differences between the estimates made by one observer and another.

It is, perhaps, premature to conclude that there have been variations in the rate of diminution of the light, but the irregularities in the curve of magnitudes seem to be rather greater than might be expected to arise from errors of observation.

In Table I., below, are given a number for reference, the names of the comparison stars used and the Harvard magnitudes on which our estimates are based.

Table II. contains the separate comparisons and remarks relating to the colour, &c.

Table III. contains the means of each observer's separate comparisons and the general mean for each night.

TABLE I.

List of Stars used for Comparison with Nova Persei.

Ref. No.	Name of Star.	Harvard Photom. Mag.	Ref. No.	Name of Star.	Harvard Photom. Mag.
1	Capella	0.18	13	β Tauri	1.90
2	Rigel	0.32	14	α Persei	1.94
3	Procyon	0.46	15	α Ursæ Maj.	1.96
4	α Orionis	0.91	16	η Ursæ Maj.	2.02
5	Aldebaran	1.00	17	β Aurigæ	2.07
6	Pollux	1.12	18	β Ursæ Min.	2.13
7	Regulus	1.42	19	γ Androm.	2.14
8	Castor	1.56	20	Polaris	2.15
9	ϵ Orionis	1.76	21	α Cassiop. (var.)	2.25
10	ϵ Ursæ Maj.	1.85	22	γ Cassiop.	2.30
11	γ Orionis	1.86	23	Algol (var.)	2.31
12	ζ Orionis	1.89	24	δ Orionis	2.36

Ref. No.	Name of Star.	Harvard Photom. Mag.	Ref. No.	Name of Star.	Harvard Photom. Mag.
25	ζ Ursæ Maj.	2.38	32	γ Ursæ Min.	3.18
26	β Cassiop.	2.42	33	δ Ursæ Maj.	3.41
27	γ Ursæ Maj.	2.56	34	ε Cassiop.	3.55
28	δ Cassiop.	2.84	35	η Cassiop.	3.64
29	ε Persei	3.04	36	ζ Cassiop.	3.74
30	γ Persei	3.11	37	η Persei	3.93
31	δ Persei	3.18			

TABLE II.

The following observations of magnitude and notes of colour were taken :—

1901.	G.M.T.	Observer.	Reference Stars.	Resulting Mag.	1901.	G.M.T.	Observer.	Reference Stars.	Resulting Mag.
	h m					h m			
Feb. 25	6 45	R.	1, 14	1.0	Feb. 25	7 0	W.	14	0.9
	7 0	W.	2	0.8		7 30	"	3	0.7
		"	14	0.9			"	8	0.6*
		"	23	0.8			"	1	0.9
		"	5	0.7			"	4	1.1
		"	4	1.0			"	3	1.0

Notes.

Observer R. Nova, bluish; Capella, yellow.

Observer W. The first six estimations were made with the 10-inch equatorial, with different powers, the remainder with naked eye. With power 100, colour of Nova bluish-white; occasionally a red marginal fringe is noticeable. Power 45: Algol, light yellow, no red fringe. Power 180: Nova, bluish-white; α Persei, light yellow; α Orionis, reddish-yellow; Aldebaran, strong yellow; Rigel, very blue.

Feb. 26	9 30	A.A.R.	$\left\{ \begin{array}{l} 23, 14, \\ 8, 6, \\ 2, 31 \end{array} \right\}$	1.0	Feb. 26	10 0	W.	6	1.3
								7	1.4
	9 47	W.	5	1.2		10 35		3	1.5
			1	1.0				14	1.1
			14	1.4				17, 1	1.1
			23	0.6				4	1.4
			4	1.3				23	0.6
			17, 1	1.1		10 0	R.	14, 1	1.4

Notes.—Observer A.A.R. By method of sequence. At 9^h 30^m, observer C., Nova is about 0.25 mag. fainter than it was February 25 8^h.

1901.	G.M.T.	Observer.	Reference Stars.	Resulting Mag.	1901.	G.M.T.	Observer.	Reference Stars.	Resulting Mag.
	h m					h m			
Feb. 27	7 15	W.	14	1.6	Feb. 27	7 15	W.	17	1.6
			8	1.6*		7 20	R.	5	1.6
			5	1.5				14	1.5
			1	1.2				23	1.6

Note.—Observer W. The comparisons with Capella and β Aurigæ are approximate only. Clouds passing.

Feb. 28	7 0	R.	5	1.6	Feb. 28	8 0	W.	10	1.6
			14	1.6		8 10		20	1.8
			23	1.7		9 45	C.	14	1.4
	8 0	W.	14	1.7				23	1.5
			23	1.6				17	1.6
			17	1.8				8	1.0*
			1	1.9				20	1.4 ($\frac{1}{2}$ wt.)
			4	1.6				15	1.3 "
			5	1.4				10	1.3 "
			7	1.7				6	1.3
			15	1.7					

Notes.—Observer W. Twilight observation at 6^h 15^m. Capella, very distinct; Nova, distinct; α Persei and Algol, invisible. At 6.30, α and ϵ Persei and Capella now visible. Nova appears brighter than α Persei and β Aurigæ. From 8^h moonlight strong, but Moon screened from observer.

Mar. 1	4 54	R.	14	1.9	Mar. 1	8 0	W.	9	1.4 ($\frac{1}{2}$ wt.)
	6 30	A.A.R.	14	2.0				24	2.0 ($\frac{1}{2}$ wt.)
			23	2.0				8	1.6*
	6 30	W.	14	1.9				20	2.4
			23	1.8				25, 16	2.2
	8 0	"	14	2.1				18	2.1
			23	2.0		7 15	R.	14	1.9
			17	1.9				23	2.0
			11	1.9		8 0	C.	14	1.9
			12	1.5 ($\frac{1}{2}$ wt.)		11 30	A.A.R.	23, 14	2.1

Notes.

Observed with transit circle, R. Nova yellow, with reddish tinge; α Persei yellow; strong contrast with Nova when at edge of field.

Observer W. Nova is reddish-yellow by contrast with α Persei and Algol. Strong moonlight troublesome. Comparison with Castor difficult; Moon near.

* Comparisons with Castor seem to indicate that the Harvard magnitude of this star is 0.3 mag. brighter than the Radcliffe estimations. On Feb. 27, 28, and Mar. 1, the Moon was near. The comparisons have not been used for Table III.

1901.	G.M.T.	Observer.	Reference Stars.	Resulting Mag.	1901.	G.M.T.	Observer.	Reference Stars.	Resulting Mag.
	h m					h m			
Mar. 2	12 0	R.	14	2.1	Mar. 2	12 0	R.	13, 14	1.9
			23	2.0					

Notes.—Nova is reddish; Algol and β Tauri are both bluish.

Mar. 3	9 15	R.	14	2.2	Mar. 3	9 15	R.	29	2.3
			13	2.0				31	2.3
			23	2.2					

Notes.— α Persei, yellow; Nova, reddish; Algol, blue.

Mar. 4 Cloudy.

Mar. 5	7 8	W.	14	2.4	Mar. 5	7 8	W.	34	2.5
			23	2.6				28	2.5
			17	2.4				22	2.5
			11	2.4				35	2.1
			12	2.1				21	2.3
			9	2.1				26	2.5
			24	2.2		7 8	R.	14	2.5
			8	2.0*				23	2.5
			20	2.4				29	2.6
			18	2.4				31	2.6

Notes.

Observed with transit circle, C. Nova reddish-yellow and fainter than α Persei.

Observer W. Moon very low in the east. Nova is very red to-night, equal to Aldebaran's tint.

Observer R. Nova is orange-red, deeper in colour than Aldebaran, α Orionis, or Mars. Algol is bluish-white.

Mar. 6	6 30	W.	23, 29	2.7	Mar. 6	8 15	W.	35	3.3
	6 50	R.	29	2.9				36	3.2
			31	2.9				19	2.6
			23	2.8				14	3.4
	8 15	W.	20	3.4				29	3.0
			18	3.3				31	2.9
			32	3.0				30	3.0
			34	3.1				37	3.4
			28	3.0		8 45		27, 33	3.0
			22	2.7		9 45	C.	31	3.0
			26	2.7				29	3.0
			21	2.6					

Notes.

Observer W. In strong twilight at 6^h 20^m: Capella, β Aurigæ, and α Persei visible; Algol and Nova, as yet, invisible. At 6.30 Nova easily visible, but ϵ Persei seen only at times. At 8.15-45, stars scintillating; much haze; colour of Nova is decidedly red. Half weight should be given to comparisons with Polaris, γ Andromedæ, and α Persei.

Observer R. Observed in clear breaks.

TABLE III.

Means of Estimations of Magnitude of Nova Persei.

1901.	G.M.T. h m	Observer.	Mean Mags.	No. of Comparisons.	Adopted Magnitude for the Night.
Feb. 25	6.45	R.	1.0	2	0.90
	7.30	W.	0.85	6 (Equatorial)	
	7.30	W.	0.91	4 (Eye)	
26	9.30	A.A.R.	0.95	2	1.17
	10.11	W.	1.17	13	
	10.0	R.	1.4	2	
27	7.15	W.	1.47	4	1.50
	7.20	R.	1.53	3	
28	7.0	R.	1.65	3	1.58
	8.5	W.	1.67	10	
	9.45	C.	1.41	7	
Mar. 1	4.54	R.	1.94	1	1.99
	6.30	A.A.R.	2.03	2	
	6.30	W.	1.88	2	
	7.15	R.	1.96	2	
	8.0	W.	2.01	10	
	8.0	C.	1.94	1	
	11.30	A.A.R.	2.13	2	
2	12.0	R.	2.05	3	2.05
3	9.15	R.	2.20	5	2.20
5	7.8	W.	2.36	15	2.42
	7.8	R.	2.54	4	
6	6.30	W.	2.67	2	2.95
	6.50	R.	2.88	3	
	8.30	W.	3.03	17	
	9.45	C.	3.01	2	

The observers were : Dr. Rambaut, indicated by A.A.R.

Mr. Wickham, " W.

Mr. Robinson, " R.

Mr. McClellan, " C.

Spectroscopic Observations.—On February 26 and March 5 the light of the star was examined with a small single prism spectroscope attached to the 10-inch Barclay equatorial. On February 26 we found a bright continuous spectrum on which were superposed several bright lines. The most conspicuous of these were one near the extreme red end of the spectrum which was taken to be C, one faint one in the orange (most probably D), and two in the green, of which the *less* refrangible was the brighter. The more refrangible of these lines was taken to be F, or possibly $H\gamma$. There were several other faint lines not identified. A bright patch was noticed in the violet, which was so condensed as to suggest a bright line out of focus. There were strong absorption bands in the orange and green, which W. at one time thought could be resolved into a series of very close dark lines.

On March 5 the general appearance of the spectrum was very similar. The absorption in the red just above C (?) and in the blue just above F (?) was very strongly marked. The C (?) line was relatively much more brilliant than on February 26, which may account for the increased redness in the light of the star, while the *more* refrangible of the two green lines now appeared the brighter. Numerous other faint lines were noticed.

Radcliffe Observatory, Oxford:
1901 March 7.

Addendum.

The following estimations were made last night :—

1901.	G.M.T.	Observer.	Ref. Stars.	Resulting Mag.	Adopted Magnitude for the Night.
Mar. 7	11.50	W.	29	2.8	2.77
			31	2.7	
	11.52	R.	29	2.7	
			31	2.8	
			30	2.9	
			14	2.7	

Notes.

W.—I think Nova is brighter than last evening, and not nearly so red.

R.—Nova has brightened, and is very red, but stars' images are scintillating considerably.

Radcliffe Observatory, Oxford:
1901 March 8.

The Variable Star R Centauri. By Alex. W. Roberts, D.Sc.

The southern variable star *R Centauri* (Ch. 5096) is a very fine example of a distinct and well-defined type of long-period variation, the type where each full light period consists of a double maximum and double minimum.

There are long-period variables that exhibit no secondary phase whatever, their variation being very regular.

For example, *S Sculptoris*, *U Centauri*, *R, V Sagittarii*, *U Pavonis*, and *T Pavonis* belong to this type.

There are also stars that exhibit secondary phases at frequent but irregular intervals. A good example of this class is the southern variable *L₂ Puppis*.

There are, however, a few stars where the secondary phases occur with marked regularity as regards period, but some irregularity as regards magnitude. Of this class of long-period stars *R Centauri* is, I think, the best example among southern variables.

The variation of *R Centauri* was discovered by Gould in 1871.

From the date of its discovery till 1878 the star was under more or less regular observation at Cordoba. On this series of observations Dr. Gould remarks, *U. A.* p. 269 :—

"The observations might be reconciled by supposing a full period of 525 days, with epoch of principal maximum 1871 April 18, and two intermediate maxima following the principal one by 197 and 378 days respectively.

"But this is incompatible with the estimates $6\frac{1}{2}^m$ and 6^m made 1874 June 25 and 26 during observations made with the meridian circle."

Although Gould's period is somewhat in error, yet he recognised the peculiar nature of the star's variation.

R Centauri has been under observation at Lovedale since 1891, and during that time six principal and five secondary maxima have been determined.

Several secondary maxima have also been observed. The principal minima, however, as they fall as low as the 13th magnitude, are beyond the reach of the telescopes at my disposal, and so the dates of this phase have been obtained by estimation only from examination of the light curve.

The magnitudes at principal maxima, while on the average $0^m.4$ brighter than the average of secondary maxima magnitudes, are singly sometimes fainter than the preceding maximum.

Thus the secondary maximum of 1900 April 5 is $6^m.1$, but the following primary maximum of 1900 November 12 is only $6^m.4$.

The dates of principal maxima observed either at Cordoba or at Lovedale are as follows :—

		Mag.	Res.
Cordoba	1871 April 15	6.1	+ 11 ^d
"	1872 Sept. 30	6.0	— 25
"	1877 Aug. 3	> 6.4	+ 33
Lovedale	1891 July 10	6.6	+ 5
"	1893 Jan. 10	5.3	— 13
"	1894 Aug. 15	6.0	+ 2
"	1896 Mar. 12	5.8	+ 7
"	1899 April 15	5.7	— 1
"	1900 Nov. 12	6.4	+ 6

These dates yield a period of

568.5 days,

and for the epoch of principal maxima

1900 November 6.

The dates of secondary maxima are :—

		Mag.	Res.
Cordoba	1872 April 20	6.7	+ 2 ^d
"	1878 June 28	6.1	— 10
Lovedale	1892 June 11	6.0	— 25
"	1894 Feb. 10	6.6	+ 24
"	1895 Sept. 2	6.5	+ 17
"	1898 Sept. 27	6.5	+ 2
"	1900 April 5	6.1	— 11

These yield a period of

568.0 days,

and for the period of secondary maxima

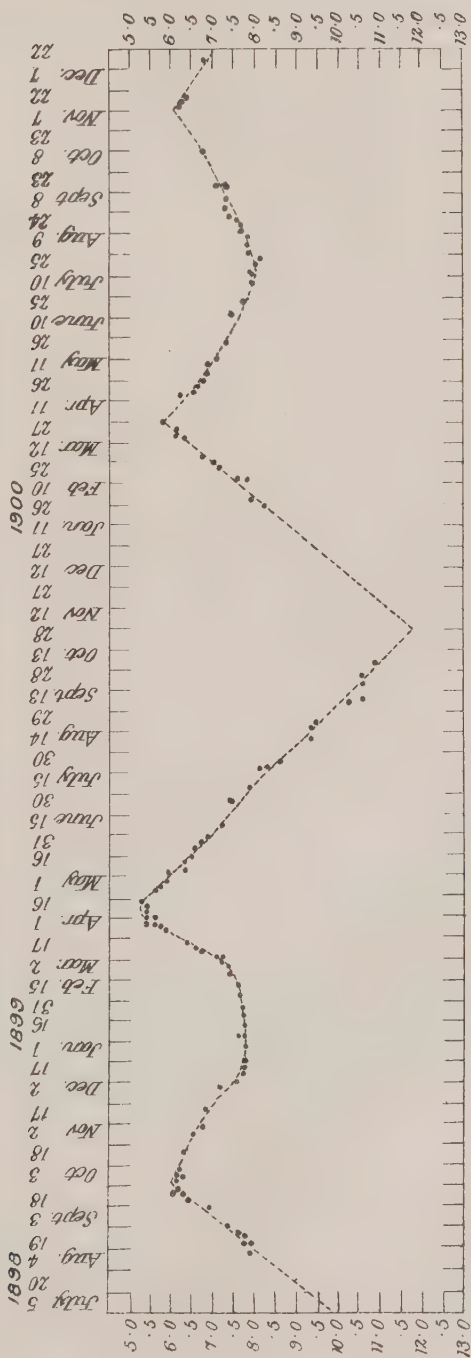
1900 April 16.'

The residuals between the observed and computed dates are given in the last column of both tables. It will be evident that they are not excessive, considering the duration of a full cycle of variation.

A secondary minimum (8^m.7) was observed by Gould 1872 August 3. The last secondary minimum observed at Lovedale was 1900 July 28 (8^m.4).

A comparison of these two dates yields a period of

567.8 days.

Light Curve of R. Centauri (Ch. 5096), 1898, 1899, 1900.

The full period of *R Centauri* may, therefore, be thus determined :—

From principal maxima,	568 ^d ·5,	weight 3
secondary maxima,	568 ^d ·0,	weight 2
secondary minima,	567 ^d ·8,	weight 1
Mean period	... 568 ^d ·2	

The full elements of the star's variation may be thus tabulated :—

Period		568 ^d ·2
Chief minimum		<i>J.D.</i> 1,414,964
Secondary maximum		5126
Secondary minimum		5228
Principal maximum		1,415,330

The two maxima follow one another at intervals of 204 and 364 days respectively, instead of 197 and 378, as Dr. Gould has it.

The period found by Dr. Gould, 525 days, is evidently due to a slip in addition, as the two combined intervals give 575 days.

Both from the Cordoba observations and the Lovedale observations there is evidence that the star at its lowest minimum sometimes reaches the 13th magnitude. To exemplify as clearly as possible the nature of the variation of *R Centauri*, the observations made at Lovedale in the years 1898–1900 have been charted down in Plate 10. During this period two full cycles have been nearly completed, and the general type of the variation can be readily seen from an examination of the light curves. In the 1898–99 period the principal maximum is distinctly brighter than the secondary maximum. The form of the light curve also between the two maxima is somewhat irregular. In the 1899–1900 observations the principal and secondary maxima are practically equal, and the form of the light curve is very regular.

The rise either to principal or secondary maximum is not markedly more rapid than the descending rate. While a rapid ascent to maximum is a characteristic of all short-period variables, it is by no means a general rule with regard to long-period variation. Indeed, there are instances where an opposite law—a more rapid decline to a minimum—seems to govern the variation of the star's light.

On the Observation of Position Angles of Polar Double Stars.

By R. T. A. Innes.

The coordinates of an equatorial telescope do not, in general, coincide with those of the sky. Error is thus introduced into measures of position angle determined with the micrometer adjusted to the instrument. This question has been considered by Chauvenet (vol. ii. pp. 393, 394), but the formula he arrives at is not adapted for use in practice. In the case of stars some distance from the pole the instrumental errors are wholly eliminated by allowing the stars to travel along the wire by diurnal motion, and so refer the zero of the position circle to the sky itself. This method was even adopted in the case of *Polaris* by Otto Struve (Pulkowa Observations, vol. ix. p. 10). Experiments show that this is a very tedious method in the case of polar stars, and one requiring repeated observations to secure accuracy. The following method is both extremely simple and accurate :—

Set on the polar star to be measured ; find the instrumental zero of the micrometer position circle by moving the telescope in declination by the slow-motion handle ; then determine the star's position angle and add to it the instrumental hour angle less the real hour angle (in arc).

The rationale is as follows :—

Adopting as far as possible Chauvenet's notation (vol. ii. p. 375) we have

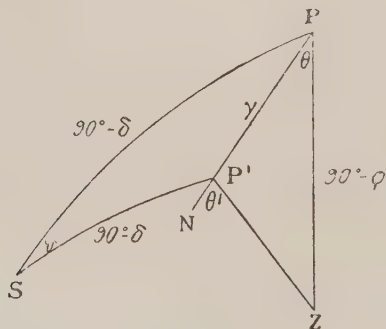


FIG. I.

P = pole of sky

S = star

ZPS = τ = hour angle of star

PS = $90^\circ - \delta$ = polar distance of star

ZPP' = θ

PP' = γ

PZ = $90^\circ - \phi$ = colatitude

P'PS = $\tau - \theta$

Po = observed position angle

P' = pole of instrument

Z = zenith

ZP'S = ι' = instrumental h. angle of star

P'S = $90^\circ - \delta'$ = instrumental p.d. of star

ZP'N = θ'

PSP' = q

ϵ = spherical excess of the triangle PSP'

PP'S = $180^\circ - \text{SP'N} = 180^\circ - (\iota' - \theta')$

p = true position angle = $P_o + q$

The sum of the three angles of PPS gives

$$q + \tau - \theta + 180^\circ - t' + \theta' = 180^\circ + \epsilon$$

whence

$$q = t' - \tau + \theta - \theta' + \epsilon$$

or putting

$$t' - \tau = \Delta\alpha$$

$$q = \Delta\alpha + \theta - \theta' + \epsilon \quad \dots \quad \dots \quad \dots \quad (A)$$

Chauvenet (vol. ii. p. 378) shows that, when the instrument is so adjusted that $\cos \gamma$ can be assumed equal to unity, we have

$$\theta - \theta' = \gamma \sin \theta \tan \phi.$$

In a fairly adjusted instrument $\gamma \sin \theta$ should be under $2'$, so that $\theta - \theta'$ is negligible. Still, should $\theta - \theta'$, which is a constant for all stars, be thought of importance, it can be computed very easily.

To evaluate ϵ we have

$$\sin \frac{1}{2} \epsilon = \frac{\sin q \sin \frac{1}{2} (90^\circ - \delta) \sin \frac{1}{2} (90^\circ - \delta')}{\cos \gamma}$$

and giving $\sin q$ a maximum value of unity, and taking $\cos \gamma = 1$ we have

δ or δ'	ϵ
80°	$52'$
85°	$12'$
88°	$2'$
$88^\circ 50'$	$0''.6$

Therefore for polar stars the equation (A) can be written

$$q = \Delta\alpha.$$

In Chauvenet's method there still remain the corrections due to error in the adjustment of the telescope with reference to its own axes. Chauvenet (vol. ii. p. 393) calls these Q , where

$$Q = 90^\circ - QSP'$$



FIG. 2.

and assumes that the zero of the position circle is perpendicular

to QS. But, as Mr. S. S. Hough has kindly pointed out to me, the zero should be found as previously indicated by setting on the polar star to be measured, and whilst the clock is driving the instrument, moving the telescope in declination until the star keeps on the wire. The zero found in this manner is freed from all errors due to instrumental causes having $\tan \delta$ or $\sec \delta$ as a factor, and the necessity to compute Q is evaded.

With instruments such as the McClean and 7-inch refractors of this observatory, where the hour circles show right ascensions direct, the difference between the instrumental R.A. and the star's R.A. gives $15 \Delta \alpha$ at once.

This method gains in accuracy as the star is nearer the pole. It is easily seen that it is applicable even if the star is situated between the pole of the sky and the pole of the instrument. All but the very minute differential effect of flexure is eliminated.

Finally, by using the above method for polar stars and the diurnal motion method for other stars, it is apparent that in neither case is a knowledge of the instrumental constants necessary in the measurement of double stars.

Royal Observatory, Cape of Good Hope :
1901 January 11.

Further Corrections to the Armagh Catalogue, with Special Reference to the "Anonymous" Stars. By J. L. E. Dreyer, Ph.D.

Shortly after I had communicated to the Society the list of corrections which appeared in the *Monthly Notices* for November (p. 10), Dr. Ristenpart, who is engaged in the preparation of a general catalogue of stars, kindly sent me a list of Corrigenda, chiefly referring to wrong degrees or minutes and similar errors. At the same time he requested me to examine the original records in order to solve a number of questions, chiefly concerning the identity of the "anonymous" stars in the Armagh Catalogue. I gladly complied with this request, as the publication of the invaluable star catalogues of the *Astronomische Gesellschaft* has now made it possible to decide many cases of doubtful identity which formerly could only have been cleared up by new observations. Some of the suggestions made by Dr. Ristenpart turned out to be correct, or at least to be very plausible; but frequently the examination of the original observations revealed very curious errors, which could never have been suspected by anyone who had not access to the originals. Many of these errors were caused by the fact that the R.A. and P.D. were observed with different instruments, and most of them could have been avoided by greater care on the part of the observers in describing the star observed and others near it, as well as in recording degrees and minutes.

In a number of cases it is necessary to assume that the observer with the transit instrument has set on a star of south instead of north declination, and *vice versa*. Up to 1844 the setting was made by either of two 6-inch setting circles at the eye end of the transit instrument, one giving altitudes, the other zenith distances, but as the working lists have not been preserved, I am unable to say whether these gave altitude (or Z.D.), or whether the observer had perhaps to find this mentally from the Decl. or P.D. of the star, though this is hardly likely to have been the case. As there is no clamp, the instrument may sometimes have been slightly displaced without the observer's knowledge, and a wrong star may have been observed in consequence.

When corrected for the errors given in the following pages, the Armagh Catalogue ought to be free from all gross errors, with the exception of one or two cases, in which I was unable to find a plausible correction.

The references Berlin, Leipzig, Harvard, &c. are to the A.G. Zone Catalogues.

94. Minutes of P.D. are 58' (error of reduction).

118. R.A. belongs to $+14^{\circ}78$ (P.D. $75^{\circ}34'$). The P.D. corrected by $-1'$ (error of obs.) is that of $+14^{\circ}89$, R.A. being $0^h 32^m 12^s$.

176 and 177 P.D. is 63° .

192. Error of reduction. R.A. should be for 1845:0 $0^h 46^m 57^s.83$. It is probably $= +23^{\circ}.126$, the observer having set 1° wrong. If so we have for 1840 $0^h 46^m 41^s.88$ (P.D. $66^{\circ}19'$) in good accordance with Berlin B. 285.

234. Minutes of P.D. must be 33 instead of 29 (Schj. 367). No minute in original obs.

272. P.D. is 17° .

302 = 303. In the latter there is an error of reduction; the seconds should be $27''.53$.

314. P.D. is 46° .

321 is marked "Comet star *e*." No magn. in original obs. except on November 23, 1845: "Very faint, $\alpha = 1^h 19^m$." Error of reduction, R.A. should be $1^h 20^m 12^s.63$, and the minute ought to be 19, as the star is B.W. $1^h.333 =$ Gött. 312.

469. Seconds of R.A. should be $24^s.25$, error of reduction.

476. Seconds of P.D. should be $14''.52$ (assumed place wrong).

492. Dr. Ristenpart suggests that if the P.D. is assumed to be $59^{\circ}30'$ instead of $56^{\circ}30' \pm$ the star is $+30^{\circ}358 =$ Leiden 836. If so, the R.A. would become $2^h 6^m 47^s.28$ or $0^s.67$ less than Leiden, so that the identity is doubtful. Reductions correct.

515. Minutes of R.A. are 14.

610. Minutes of R.A. are 39.

623. Minutes of R.A. are 47.

659. Prec. in R.A. is $3^s.469$, misprint.

819. Seconds of P.D. should be $18''.37$. All the corrections are $10''$ too great.

873. R.A. ($4^h 0^m 16^s.68$, see errata) belongs to $+54^\circ.745$ (P.D. $= 36^\circ 1'$). N.P.D. if corrected by $+10'$ is that of No. 877. No error of reduction.

898. Observed 1849 February 13 (not January), $3^s.26$ following 50 *Tauri*, therefore α is $20^s.00$ too small, and $\star = +20^\circ.725$.

899. Error of reduction in α ; it should be $4^h 7^m 39^s.69 =$ No. 900 $=$ G. 806. In P.D. the observer has altered the observed minute from 37 to 38, but if we reject this correction we get $29^\circ 39' 18''.1$ in excellent accordance with G. 808 and Radcl. 1189 (R.A. $= 4^h 7^m 55^s$).

922. P.D. minute should be 35.

1087. Prec. in R.A. should be $8^s.299$ (used in reductions).

1140. R.A. is $1^s.00$ too great (error of reduction).

1170. Seconds of P.D. should be $48''.63$ (error in assumed place).

1202. Prec. in R.A. is $3^s.094$, also an error of 1^s in the reduction, so that R.A. becomes $5^h 20^m 26^s.08$ (P.D. $= 88^\circ 55'$). Star is B.W. $5^h.508$.

1257. The R.A. is given for 1850. For 1840 it becomes $5^h 29^m 16^s.90$. Star is $+7^\circ.952$.

1266. Minutes of R.A. are 30.

1296. Prec. in R.A. is $3^s.429$ (used).

1343. There are here two stars nearly on the same parallel, $\Delta\alpha = 23^s$. Doubtless the P.D. belongs to the preceding one, $+24^\circ.1039 =$ Berlin B. 2074, which is for 1840 $65^\circ 24' 53''.3$. R.A. $= 5^h 47^m 48^s$.

1438. P.D. should be $37''.93$ (error in changing "assumed place" from *Naut. Alm.* to A.S.C.).

1439. Observer has given α as $6^h 17^m$. I cannot find why the star was observed, nor why α was altered. It is therefore $= +13^\circ.1250 =$ Leipz. 2260. With correct precession we get $76^\circ 48' 30''.58$, $\alpha = 6^h 17^m 38^s$.

1450. P.D. should be $18''.71$ (error of reduction).

1451. R.A. is $6^h 18^m 13^s \pm$.

1454. The minute observed is 16 (not 17), but it ought to be 15, as the star must be $= +0^\circ.1405$, P.D. being $89^\circ 36'$.

1490. Probably $= 1491$. Observed for a "Halley's comet star" with the note "not the star." With the constants and precession of 1491 the R.A. becomes $6^h 24^m 40^s.12$.

1494. The only star with this P.D. is $+33^\circ.1328 =$ B.W. $6^h.517$, the R.A. of which is $6^h 17^m 41^s$. The seconds of P.D. would be $17''.77$. Also observed for a comet star.

1498. Prec. in R.A. is $3^s.915$.

1503. R.A. of this and P.D. of 1509 belong together, $= +33^\circ.1371$, while the R.A. of 1509 belongs to $+34^\circ.1416$, P.D. $55^\circ 34'$.

1559. R.A. belongs to $+8^\circ.1543 =$ Leipzig II. 3300, P.D. $= 81^\circ 26'$.

1561. The R.A. of this and the P.D. of 1559 form $+8^\circ.1544 =$ Leipzig II. 3303.

1594. Seconds of P.D. should be $37''\cdot75$ (error of reduction).
 1620. Dr. Ristenpart suggests that if corrected by -1^m this would be $= +15^{\circ}\cdot1482 =$ Berlin A. 2643 (P.D. $74^{\circ} 19'$). No error of reduction, observed for 45 *Geminorum*.

1628 is $+15^{\circ}\cdot1496 =$ Berlin A. 2675, P.D. $74^{\circ} 34'$.

1630 is $+15^{\circ}\cdot1497 =$ Berlin A. 2679. P.D. $74^{\circ} 34'$.

1655 P.D. degrees are 86° (misprint).

1839 Prec. in R.A. is $4^s\cdot677$ (misprint).

1855 Minutes of R.A. are 11.

1911 } Seconds of R.A. are 44 and 46 ; corrections to P.D.

1912 } for precession are respectively $-0''\cdot53$ and $-0''\cdot61$.

1917. The P.D. must belong to 41 *Canceri*, as P. 128 (observed with micrometer) is said to precede it.

1920. P.D. $-1'$ makes the star $= 1925$. This error of observation equally affects 1922 (the $\Delta\delta$ of which from 1920 was measured by the micrometer) which then is $= 1923$.

1921, $\Delta\delta$ measured from 42 *Canceri* ; observer adds "north of two preceding." So it must be $+20^{\circ}\cdot2165 =$ Berlin B. 3489.

1937. Observed with the micrometer as *a* comes to δ *Canceri*, but it is not stated whether it is *p* or *f*. $\Delta N.P.D. = +22''\cdot2$, but there must be some error of observation, as the star can only have been No. 1931, which then was $65''$ south of δ *Canceri*. No plausible correction to the recorded measure will, however, change $22''$ into $65''$.

1946. Minute of P.D. is $1'$.

1965. The first two observations give the minute of P.D. as 19 and 29, while the third gives neither degree nor minute. It was observed for 52 *Canceri*, and must be either this star ($73^{\circ} 24'$) or $+16^{\circ}\cdot1834$ ($73^{\circ} 14'$).

2002. Probably $= 2001$ with an error of $5'$. If so, seconds become $23''\cdot89$.

2041 is $= 2040$ with an error of $1'$.

2060. Dr. Ristenpart proposes to read $103^{\circ} 3'\pm$ for $103^{\circ} 54'\pm$, the star being $-13^{\circ}\cdot2825$. The observer set for P. 39.

2162. Observed over six wires. Is it $= 2160$ with an error of 20 in counting the seconds? Dr. Robinson remarked afterwards that there is no star in the place of 2162.

2238 $= +83^{\circ}\cdot296$. I cannot make out how the places given in the Catalogue were found. $\Delta\alpha$ from P. X. 22 :—

	^s		^s
Apparent	$-46\cdot17$	mean	$-46\cdot18$
	$46\cdot33$		$46\cdot34$
	$45\cdot67$		$45\cdot38$
	$46\cdot13$		$46\cdot14$

Place for 1840 : $10^h 10^m 8^s\cdot26$, $6^{\circ} 31'\cdot3$.

2281. The observer set for 31 *Sextantis*. He notes : "Double, the large taken" (*i.e.* the sf one by a diagram). The star is

therefore Σ 1440, and he must have set for -3° instead of $+3^\circ$.
P.D. $93^\circ 5'$.

2307 is = 2308, Groombridge being 30^s wrong.

2319 = Schj. 3899, R.A. = $10^h 31^m 49^s$.

2355. The R.A. is that of $+70^\circ 635 = A.\ddot{O}.$ 11184, the P.D. of which is $19^\circ 16'0$, while the P.D. is that of $+70^\circ 625 = A.\ddot{O}.$ 11109, the R.A. of which is $10^h 36^m 56^s$.

2357. Minutes of P.D. are $38'$.

2395. The observer believed he had set for P.X. 221 and put down the P.D. of that star; but he must have set for $90^\circ 41'$ instead of $89^\circ 14' \pm$, as the R.A. observed is that of Gött. 3585.

2398. P.D. should be $90^\circ 42'$, Gött. 3589. Note to this and 2395 in Second Armagh Catalogue to be cancelled.

2479 = 2478.

2520. R.A. is wrong. It precedes 92 *Leonis* $1^m 16^s.42$ and is = $+22^\circ 2387 =$ Berlin B. 4323. $11^h 31^m 11^s.15$, $67^\circ 48' \pm$.

2584. The observer remarks 1844 Apr. 16: "The large * following is also bisected." This large star must have been 67 *Ursæ*, which has a P.M. of $+0''060$ in P.D. and in 1844 was exactly on the parallel of $+43^\circ 2177 =$ Bonn 8308. Therefore this was the star observed with an error of $5'$, which error must also have been made in 1854, though perhaps it was 67 *Ursæ* which was observed 1854 April 1. The R.A. of 2584 is $11^h 53^m 19^s$, P.D. $46^\circ 3' 58''$.

2607. Dr. Ristenpart suggests that the observer set for $-6^\circ 53' \pm$ instead of for $+6^\circ$ and that the star is B.W. $12^h 27 =$ Schj. 4390. Observed instead of 11 *Virginis*.

2611. Minute of R.A. should be 2^m , no minute in original observations (= Radcliffe 2803).

2674. Observed instead of 2676. The R.A. of $+37^\circ 2278$ in the Lund zones agrees well, but the P.D. of this star for 1840 is $52^\circ 45'$, so that even an error of 10° in setting would leave $26'$ not accounted for. An error of 1° would bring us to Cambridge 6122 ($64^\circ 11'$) but this differs more than a second in R.A.

2711. Seconds of P.D. are $27''.34$, error of reduction.

2807. Seconds of R.A. should be $29^s.68$, P.D. $61^\circ 31$. Star is $+28^\circ 2185 =$ Cambridge 6356 = Armagh 2805.

2815. P.D. must be $99^\circ 57'$ as B.W. $13^h 22$ seems the only star possible.

2909. Minutes of P.D. are $33'$, error of reduction.

3025. Minute of P.D. must be $17'$ according to Berlin A. 5159.

3042. I cannot identify this star; reductions correct, except that the first R.A. should be $33^s.24$. Observed for P. xiv. 52.

3075. Dr. Ristenpart suggests that the instrument was set to P.D. $40^\circ 30'$ instead of $39^\circ 30'$, and that the star is $+49^\circ 2305$.

3095. Minutes of P.D. are 53 (misprint).

3137. P.D. is $57^\circ 19' 47''.70$, R.A. = $14^h 47^m 39^s$. The "corrections" must have been applied to a wrong "assumed place" when making up the final catalogue.

3178. Minutes of P.D. are $37'$, error of observation.
 3212. Seconds of R.A. are $38^s.61$, error of reduction.
 3425. Prec. in P.D. is $8''.134$.
 3444. Correction should be $-6''.99$ and seconds of P.D. $42''.42$.
 3461. Minutes of P.D. are 28.
 3544. P.D. is $91^\circ 20' 11''.31$; the minute only noted once, and there is an error in the reduction to 1840.
 3600. On p. 767 the figure 1 has dropped out ($41''.87$).
 3651. Observed for 6 *Sagitt.*, there seems no star possible except $-15^\circ 47'67$, P.D. $105^\circ 48'$.
 3674. Minutes of R.A. are 54.
 3714. P.D. is 77° ; corrections $+4''.43$ and $+3''.13$. Seconds $2''.74$.
 3721. Dr. Ristenpart suggests that the instrument was set to 39° instead of 33° , in which case the star would be $+50^\circ 25'49$ = Harvard 5526, P.D. $39^\circ 5'$. The conjecture is probably right, and the R.A. would then be $18^h 11^m 30^s.95$.
 3729 = 3727 = L.L. 33792, Baily's R.A. being 28^s out.
 3745 would seem to be Schj. 6710, P.D. $92^\circ 32'$.
 3758 Minutes of P.D. are $51'$.
 3777. Dr. Ristenpart suggests that this is $+22^\circ 33'85$ = Berlin B. 6500, P.D. $67^\circ 20'$.
 3835. Minutes of R.A. are 36 = 3831, error of reduction.
 3844. Minute of R.A. must be 41. Schj. 6969.
 3902. Dr. Ristenpart thinks that this is Schj. 7054, P.D. $90^\circ 40'$ instead of $87^\circ 40'$. The error must have been in the working list, as the same wrong setting was made on two nights. Observed for 64 *Serpentis*.
 3908. To be struck out. Simply a repetition of 3909.
 3940. Degrees of P.D. are 61° , not 16. In original " $21^s.5$ p. P. 318."
 3970. P.D. is $63^\circ 25'.4$.
 3980. Dr. Ristenpart suggests that the P.D. was $84^\circ 15'$ instead of $94^\circ 15'$, which would alter the seconds of R.A. to $55^s.34$ and make the star = Leipzig. II. 9118.
 3982. Minutes of R.A. are 9^m , = $-1^\circ 37'01$; clerical error.
 3985. P.D. must be $70^\circ 2' \pm$, seconds of R.A. $5^s.09$.
 4003. There is an error of 1^m in the first observation; single results are $28^s.45$ and $28^s.27$. R.A. = $19^h 9^m 28^s.36$ P.D. $24^\circ 10'$.
 4043. P.D. is $105^\circ 30'$.
 4088. Is a "comes preceding" to 10 *Cygni*, $\Delta\delta$ measured $1' 26''.53$, not stated whether north or south. It must be $+51^\circ 21'57$, south of 10 *Cygni*. $19^h 24^m 29^s, 38^\circ 37' 55''.03$ in good agreement with Harvard 6035.
 4100. Seconds of R.A. are 24. Munich, 8938.
 4110. Dr. Ristenpart suggests that it is $-2^\circ 50'57$, P.D. $92^\circ 40'$. Observed for P. xix. 183.
 4163. Prec. in R.A. is $2^s.824$, misprint. P.D. $78^\circ 28'$.

4210 is G. 2978, and has been reduced on that supposition. By obs. it is $2^m 13^s.33$ p. G. 2991, which gives $19^h 49^m 58^s.12$, which is $4^s.0$ less than Radcliffe 4509. There must be an error in counting the seconds. Only three wires observed, which agree very badly.

4221. This star was observed in the usual way and G. 2984 was by micrometer found to be $48''.37$ south of it. There is an error of reduction, P.D. should be $50^\circ 2' 41''.10$. It seems to be $= +39^\circ 39'66$, though this star is only of 9.2 mag.

4226. In the original note-book this is described as "G. 3057 (o. ed.)," with another 5^s following. This means that the observer set for No. 3057 of the suppressed edition of Groombridge's catalogue* or G. 2988 = Radcliffe 4524, and the wire transits have indeed been reduced with $\delta = 43^\circ 50'$. A sketch made agrees with the relative positions of $+43^\circ 34'22-23-25$. For some unknown reason the two stars observed were afterwards taken to be an anonyma and P. xix. 354 in P.D. 52° ! Properly reduced we get for 1840

$$\begin{array}{rcccl} & h & m & s & \\ 4226 & 19 & 51 & 40.39 & 46^\circ 9' \\ 4228a & & 51 & 45.67 & 46^\circ 5' \end{array} \left. \vphantom{\begin{array}{rcccl} & h & m & s & \\ 4226 & 19 & 51 & 40.39 & 46^\circ 9' \\ 4228a & & 51 & 45.67 & 46^\circ 5' \end{array}} \right\} \text{Epoch 1842.638.}$$

4228. The first result in R.A. to be struck out, seconds $= 45^s.20$, epoch 1850.997.

4230 follows 10^s after 4228, and is therefore $= +38^\circ 38'36$. For 1840

$$19^h 51^m 55^s.31 \quad 52^\circ 1'.$$

$$4231 = 4230 = \text{L.L. } 38172 = 4233.$$

$$4360. \text{ For 1844 October 28 read August 28.}$$

$$4361. \text{ Observed } 1^s.28 \text{ p } 4360, \text{ therefore } = +9^\circ 45'07 = \text{B.W. } 20^h.400.$$

$$20^h 15^m 44^s.95 \quad 80^\circ 6'.$$

4388. Two different stars. Minutes of R.A. should be 20 (obvious error of obs.), and its P.D. is $60^\circ 9'.3 (= +29^\circ 40'38)$. The R.A. of the star observed in P.D. is $20^h 22^m 39^s (= +29^\circ 40'55)$.

4421. The R.A. is that of $+34^\circ 40'82$, P.D. $55^\circ 12'$, but the star observed in P.D. was $1' 56''.16$ south of 47 *Cygni* and is described as "very faint companion." It must have been $+34^\circ 40'76$, 9.5 mag., 16^s p, $1'.3$ south, R.A. $= 20^h 27^m 24^s$.

4579 and 4580. "Two of same R.A.," therefore $= +55^\circ 25'29 - 30$, R.A. $= 21^h 3^m 51^s$ and 52^s .

4593. Minutes of P.D. are 27. Prec. in R.A. is $1^s.508$ (misprint).

4636. Dr. Ristenpart suggests that the P.D. was $71^\circ 36'$ and the star $= +18^\circ 47'72$.

* About this see p. v of the published Catalogue. There is a copy of it in the library of Armagh Observatory.

4641. Degrees of P.D. are 100 (misprint).

4645. Must be $= +36^{\circ}45'22$, R.A. $21^h 14^m 6^s$, seconds $18''90$.

4646. Must be $= +36^{\circ}45'34$, R.A. $21^h 15^m 58^s$, seconds $25''28$.

4673. Minutes of P.D. are 17.

4678=P. xxi. 158=B.A.C. 7473. Minutes should be 22^m , error of obs.

4790. Measured by micrometer $+1' 43''30$ from 4789, is therefore south of the latter. The observer at first thought he had observed 4785 (no degrees or minutes recorded!) and a comes, hence the erroneous position of 4790. It is

$$+53^{\circ}27'41, 21^h 49^m 42^s, 36^{\circ} 51' 8''27.$$

4793. I cannot explain how the P.D. $16^{\circ} 54' \pm$ was made out, as the wire transits have been reduced with P.D. $18^{\circ} 45'$, and thus the five wires observed agree very well indeed. The constants of 79 *Draconis* (or a star near it) were used, and an error of 1^s was made. In the original the minute observed is recorded as 50 with a 1 written over the 0, and the 0 has been adopted, which happens to be wrong. It is $+71^{\circ}10'97$ =Radcliffe 5473, and reduced anew it becomes $21^h 50^m 41^s.12$ (Prec. $+0^s.966$), $18^{\circ} 46'$.

4798. Must be $-13^{\circ}60'72$, R.A. $21^h 52^m 15^s$ (9.2 mag.).

4808. If minutes of R.A. are taken as 52 instead of 53, the R.A. agrees with that of Leipzig II. 11065= $+7^{\circ}47'77$, P.D. $82^{\circ} 54'$. Observed for 19 *Pegasi*.

4810. Minutes of P.D. are 42 (misprint).

4830. R.A. is $22^h 0^m 20^s$ ($=+62^{\circ}20'30$).

4845. Dr. Ristenpart suggests that the P.D. was $95^{\circ} 43'$ instead of $94^{\circ} 40' \pm$, as the star must have been B.W. $22^h 29^m = -5^{\circ}57'20$.

4855. } The first is Bradley 2935=G. 3707, the second is
4858. }

G. 3709. On 1844 October 10 the observer says "the preceding star," but a diagram shows the following star bisected on the horizontal wire. On 1850 November 27 he adds "took the brightest." The preceding star is the brightest, and, no doubt, it was observed on the other occasions when no note was made. The P.D.'s of 4855 and 4858 are therefore to be interchanged, after which they will be in excellent accordance with Radcliffe, Greenwich, and Σ 2873.

4918. P.D. should be $48^{\circ} 44' 53''44$.

4960. Must be $=+12^{\circ}48'43$, P.D. $77^{\circ} 25'$.

4964=4966=L.L. 44154.

4968=4969.

4971. Stated by observer to follow 4960, therefore $=+12^{\circ}48'49$, P.D. $77^{\circ} 21'$.

5080. See p. 613. I cannot identify this star: it was measured by micrometer $+3' 37''21$ (south) from α Andromedæ. It is called a "comes," but as usual there is not a word about the magnitude nor about the difference of R.A. $+41^{\circ}46'60$ (9.4 mag.) is $1^m 40^s$ p α Androm., $3'5$ north.

5114. Must be several minutes preceding B. 3077, as it was observed in the usual way with four microscopes before B. 3077 came into the field. It is therefore $= +56^{\circ}.2952$, R.A. $23^h 1^m 30^s$. How the R.A. of this and other anonymous stars came to be given to a second in the Catalogue, though only given roughly to the nearest minute in the "observed places," is altogether a mystery.

5141. Must be G. 4025, which is $1^m 45^s$ p and $1' 50''$ north of G. 4029. The former was observed on the fixed wire with four microscopes, and the latter was measured with the micrometer, $\Delta\delta = 1' 16'' .97$. I can only suppose that the instrument was accidentally displaced after setting on the first star and before setting on the second star. This would explain why the place of the first star is wrong, while that of the second is right.

5177. Measured from 4 *Cassiopeia*, minutes of P.D. should be 36. On November 17 it is called "preceding, 9 mag.," on November 20 only "comes." $+61^{\circ}.2448$ is the only star, but it follows 4 *Cassiopeia* 58^s , $1' .2$ south, R.A. being $23^h 18^m 44^s$.

5190. Observed with 5193, "preceding, exactly bisected, 7 mag." No Δa given. Not mentioned on the other nights when 5193 was observed, and looked for in vain in 1859 and 1865. It must have been a minor planet, the magnitude may have been exaggerated.

5295. Minutes of P.D. are 19, error of reduction, R.A. $= 23^h 49^m 50^s$.

5322. Minutes of R.A. are 54, it follows $2^s .49$ after B. 3202.

5338. Degrees of P.D. are 86.

5339 } Are mere repetitions of 4154 and 4357.

5340 }

Finally, in the Appendix, p. 828, β *Cassiopeia*, the minutes of P.D. should be 43.

Note on Mr. Bryan Cookson's Paper, "On the Accuracy of Eye Observations of Meteors and the Determination of their Radiant Points." By H. C. Plummer, M.A.

1. Mr. Cookson's paper must be regarded as a welcome and valuable attempt to deal with a question of great importance and interest. It is the more necessary, therefore, to point out an error which occurs in his theory. The correction is offered here with no idea of detracting from the merit of the author's contribution, and it is believed that his oversight in no way affects the validity of his general conclusions.

2. The error occurs in the expression which Mr. Cookson obtains for the weight of an equation. The result ought to be simplified by the suppression of the Q term. It seems clear on general grounds that the weight ought to be independent of the

directions of the axes, and it was this consideration which led me to suspect the accuracy of the expression. I am not concerned to criticise Mr. Cookson's assumptions as to the nature of the probable errors of the recorded observations. I admit, moreover, the principle according to which mean errors are obtained from a linear differential relation, though it must be borne in mind that this goes deeper than the assumption of a definite form of probability function. For since higher powers of the errors are neglected in comparison with the first in the differential relation, fourth and higher powers can be neglected in the probability function.* The clearest, if not perhaps the shortest, method of treating the question is to express p directly in terms of the observed quantities.

3. I retain as far as possible Mr. Cookson's notation. Let b_1, b_2 be the extremities of the projection of the meteor's path, and let $Ob_1b_2 = \psi_1, Ob_2b_1 = \psi_2$. Now

$$\delta p = \frac{\partial p}{\partial r_1} \cdot \delta r_1 + \frac{\partial p}{\partial \theta_1} \cdot \delta \theta_1 + \frac{\partial p}{\partial r_2} \cdot \delta r_2 + \frac{\partial p}{\partial \theta_2} \cdot \delta \theta_2.$$

By assumption $dr_1, \sin r_1 d\theta_1, dr_2, \sin r_2 d\theta_2$ are displacements in the sense of which errors are independent and equally likely to the same amount. Hence

$$\epsilon_p^2 = \frac{\epsilon^2}{2} \left\{ \left(\frac{\partial p}{\partial r_1} \right)^2 + \left(\frac{1}{\sin r_1} \cdot \frac{\partial p}{\partial \theta_1} \right)^2 + \left(\frac{\partial p}{\partial r_2} \right)^2 + \left(\frac{1}{\sin r_2} \cdot \frac{\partial p}{\partial \theta_2} \right)^2 \right\}.$$

The polar coordinates of b_1, b_2 are $(\lambda \tan r_1, \theta_1)$ and $(\lambda \tan r_2, \theta_2)$, and therefore

$$\begin{aligned} p &= \sqrt{\frac{\lambda \tan r_1 \tan r_2 \sin(\theta_2 - \theta_1)}{\{\tan^2 r_1 + \tan^2 r_2 - 2 \tan r_1 \tan r_2 \cos(\theta_2 - \theta_1)\}}} \\ \therefore \frac{1}{p} \cdot \frac{\partial p}{\partial r_1} &= \frac{\sec^2 r_1}{\tan r_1} - \frac{\tan r_1 - \tan r_2 \cos(\theta_2 - \theta_1)}{\tan^2 r_1 + \tan^2 r_2 - 2 \tan r_1 \tan r_2 \cos(\theta_2 - \theta_1)} \sec^2 r_1 \\ &= \frac{\sec^2 r_1 \cdot \tan r_2 \{\tan r_2 - \tan r_1 \cos(\theta_2 - \theta_1)\}}{\tan r_1 \cdot D^2 / \lambda^2} \\ &= \frac{\lambda^2 + \rho_1^2}{D^2} \cdot \frac{\rho_2}{\rho_1} \cdot \frac{\rho_2 - \rho_1 \cos(\theta_2 - \theta_1)}{\lambda} \\ &= \frac{\lambda^2 + \rho_1^2}{D^2} \cdot \frac{\rho_2}{\rho_1} \cdot \frac{D \cos \psi_2}{\lambda} \\ &= \frac{(\lambda^2 + \rho_1^2) \cdot \sqrt{(\rho_2^2 - p^2)}}{D \lambda \rho_1} \end{aligned}$$

* Bertrand, *Calcul des Probabilités*, p. 267.

Also

$$\begin{aligned}
 \frac{1}{p} \cdot \frac{\partial p}{\partial \theta_1} &= -\cot(\theta_2 - \theta_1) + \frac{\tan r_1 \tan r_2 \sin(\theta_2 - \theta_1)}{\tan^2 r_1 + \tan^2 r_2 - 2 \tan r_1 \tan r_2 \cos(\theta_2 - \theta_1)} \\
 &= -\frac{\cos(\theta_2 - \theta_1)(\tan^2 r_1 + \tan^2 r_2) + \tan r_1 \tan r_2 (1 + \cos^2 \theta_2 - \theta_1)}{\sin(\theta_2 - \theta_1) \cdot D^2 / \lambda^2} \\
 &= \frac{(\tan r_1 - \tan r_2 \cos \theta_2 - \theta_1)(\tan r_2 - \tan r_1 \cos \theta_2 - \theta_1)}{\sin(\theta_2 - \theta_1) \cdot D^2 / \lambda^2} \\
 &= \left\{ \frac{2\rho_1^2 - (\rho_1^2 + \rho_2^2 - D^2) \{2\rho_2^2 - (\rho_1^2 + \rho_2^2 - D^2)\}}{4\lambda^2 \rho_1 \rho_2 \cdot \sin(\theta_2 - \theta_1) \cdot D^2 / \lambda^2} \right\} \\
 &= (D^2 + \rho_1^2 - \rho_2^2)(D^2 + \rho_2^2 - \rho_1^2) / 4pD^3 \\
 &= \rho_1 \rho_2 \cos \psi_1 \cos \psi_2 / pD \\
 \therefore \frac{\partial p}{\partial \theta_1} &= \sqrt{(\rho_1^2 - p^2)} \cdot \sqrt{(\rho_2^2 - p^2)} / D
 \end{aligned}$$

Hence

$$\begin{aligned}
 \left(\frac{\partial p}{\partial r_1} \right)^2 + \left(\frac{1}{\sin r_1} \cdot \frac{\partial p}{\partial \theta_1} \right)^2 &= \frac{(\lambda^2 + \rho_1^2)^2 (\rho_2^2 - p^2) p^2}{D^2 \lambda^2 \rho_1^2} \\
 &\quad + \frac{(\rho_1^2 - p^2)(\rho_2^2 - p^2)}{D^2} \cdot \frac{\lambda^2 + \rho_1^2}{\rho_1^2} \\
 &= \frac{(\lambda^2 + \rho_1^2) (\rho_2^2 - p^2)}{D^2 \lambda^2} (p^2 + \lambda^2)
 \end{aligned}$$

Similarly

$$\begin{aligned}
 \left(\frac{\partial p}{\partial r_2} \right)^2 + \left(\frac{1}{\sin r_2} \cdot \frac{\partial p}{\partial \theta_1} \right)^2 &= \frac{(\lambda^2 + \rho_2^2) (\rho_1^2 - p^2)}{D^2 \lambda^2} (p^2 + \lambda^2) \\
 \therefore \epsilon_p^2 &= \frac{\epsilon^2}{2} \cdot \frac{1}{\lambda^2 D^2} (\lambda^2 + p^2) \{ (\lambda^2 + \rho_1^2) (\rho_2^2 - p^2) + (\lambda^2 + \rho_2^2) (\rho_1^2 - p^2) \} \\
 &= \frac{\epsilon^2}{2} \cdot \frac{1}{\lambda^2 D^2} \cdot (\lambda^2 + p^2) P
 \end{aligned}$$

where P has precisely the same meaning as in Mr. Cookson's paper. Thus the formula for the weight of an equation is actually simplified to the extent of omitting the quantity Q.

4. It is now a matter of some interest to consider in what way Mr. Cookson's procedure is in fault. The forms found for ϵ_x and ϵ_y are right, but the author errs in applying them because the quantities x and y to which they refer are subject to errors which are not independent. That the contrary supposition is erroneous may be seen thus. The probabilities of errors ξ and η in x and y are proportional to $\exp. (-\xi^2 / 2\epsilon_x^2)$, and $\exp. (-\eta^2 / 2\epsilon_y^2)$. Therefore if such errors were independent, the probability of their concurrence would be proportional to $\exp. (-\xi^2 / 2\epsilon_x^2 - \eta^2 / 2\epsilon_y^2)$, and the locus

of equally likely resultant error would be $\xi^2/\epsilon_x^2 + \eta^2/\epsilon_y^2 = \text{const.}$, or an ellipse with axes parallel to the coordinate axes. But as a matter of fact this locus is the projection of a small circle on the sphere, and therefore an ellipse whose major axis passes through the origin. The locus on the sphere is given by $(\delta r)^2 + \sin^2 r (\delta \theta)^2 = \text{const.}$ Now since $r = \tan^{-1} \frac{\rho}{\lambda}$ and $\theta = \tan^{-1} \frac{y}{x}$ we have

$\delta r = \frac{x\delta x + y\delta y}{\rho(\rho^2 + \lambda^2)} \lambda$ and $\delta \theta = \frac{x\delta y - y\delta x}{\rho^2}$. Hence the locus of equal probability on the plane of projection is

$$\frac{(x\delta x + y\delta y)^2 \lambda^2}{\rho^2(\rho^2 + \lambda^2)^2} + \frac{(x\delta y - y\delta x)^2}{\rho^2(\rho^2 + \lambda^2)} = \text{const.},$$

δx and δy being the current coordinates relative to (x, y) considered fixed. This reduces to

$$\frac{\xi^2}{\rho^2 + \lambda^2} + \frac{\eta^2}{\lambda^2} = \text{const.}$$

when the axes are taken through (x, y) , so that one, $\eta = 0$, passes through the origin.

5. It may be useful to consider the question of independence in more general terms.* In ordinary mathematical operations it is possible to pass by processes of transformation from one set of quantities susceptible of variation to another set in such a way that the latter group contains the necessary elements of independence. Thus in general the same operations may be performed after the transformation as before. As regards the question in the theory of probability considered here, the same is not the case. In some instances the answer to the question is obvious; as, for example, when the number of quantities in the second set exceeds the number in the first (or at least generally in this case), or when the quantities of the second set can be expressed individually in terms of different members of the first set. It is when we have the same number of quantities in each set, as in the example discussed above, that the question is most interesting and most likely to be misunderstood.

6. Let $X_1, X_2 \dots X_n$ be a set of quantities determined by direct observation, wholly independent and with mean errors denoted by $\epsilon(X_1) \dots$. Suppose $Z = \phi(Y_1, Y_2 \dots Y_m)$, where $Y_1 = f_1(X_1, X_2 \dots X_n)$, $Y_2 = f_2 \dots$, $Y_m = f_m$.

Let $X_1, X_2 \dots X_n$ be the true (or approximate assumed) values, and from these let $Y_1, Y_2 \dots Y_m$, and Z be derived. Then if $x_1, x_2 \dots x_n$ are the small quantities $X_1 - \bar{X}_1, X_2 - \bar{X}_2 \dots X_n - \bar{X}_n$,

$$\bar{Z} = Z - \frac{dZ}{dX_1} \cdot x_1 - \frac{dZ}{dX_2} \cdot x_2 - \dots - \frac{dZ}{dX_n} \cdot x_n$$

* Cf. *Chauvenet's Astronomy* (5th ed.), vol. ii. p. 502.

or

$$Z = \bar{Z} + \left(\frac{\partial Z}{\partial \bar{Y}_1} \cdot \frac{\partial Y_1}{\partial \bar{X}_1} + \frac{\partial Z}{\partial \bar{Y}_2} \cdot \frac{\partial Y_2}{\partial \bar{X}_1} + \dots + \frac{\partial Z}{\partial \bar{Y}_m} \cdot \frac{\partial Y_m}{\partial \bar{X}_1} \right) x_1 + \dots$$

Hence

$$\begin{aligned} [\epsilon(Z)]^2 &= \left[\frac{\partial Z}{\partial \bar{Y}_1} \cdot \frac{\partial Y_1}{\partial \bar{X}_1} + \frac{\partial Z}{\partial \bar{Y}_2} \cdot \frac{\partial Y_2}{\partial \bar{X}_1} + \dots + \frac{\partial Z}{\partial \bar{Y}_m} \cdot \frac{\partial Y_m}{\partial \bar{X}_1} \right]^2 [\epsilon(X_1)]^2 \\ &\quad + \dots \\ &\quad + \left[\frac{\partial Z}{\partial \bar{Y}_1} \cdot \frac{\partial Y_1}{\partial \bar{X}_n} + \frac{\partial Z}{\partial \bar{Y}_2} \cdot \frac{\partial Y_2}{\partial \bar{X}_n} + \dots + \frac{\partial Z}{\partial \bar{Y}_m} \cdot \frac{\partial Y_m}{\partial \bar{X}_n} \right]^2 [\epsilon(X_n)]^2 \\ &= \sum_{i=1}^{i=n} [\epsilon(X_i)]^2 \left[\sum_{j=1}^{j=m} \frac{\partial Z}{\partial \bar{Y}_j} \cdot \frac{\partial Y_j}{\partial \bar{X}_i} \right]^2 \end{aligned}$$

7. On the other hand

$$Y_j = \bar{Y}_j + \frac{\partial Y_j}{\partial \bar{X}_1} \cdot x_1 + \frac{\partial Y_j}{\partial \bar{X}_2} \cdot x_2 + \dots + \frac{\partial Y_j}{\partial \bar{X}_n} \cdot x_n^1$$

$$\begin{aligned} \text{and } [\epsilon(Y_j)]^2 &= \left(\frac{\partial Y_j}{\partial \bar{X}_1} \right)^2 [\epsilon(X_1)]^2 + \left(\frac{\partial Y_j}{\partial \bar{X}_2} \right)^2 [\epsilon(X_2)]^2 \\ &\quad + \dots + \left(\frac{\partial Y_j}{\partial \bar{X}_n} \right)^2 [\epsilon(X_n)]^2 \end{aligned}$$

$$\text{But } Z = \bar{Z} + \frac{\partial Z}{\partial \bar{Y}_1} \cdot y_1 + \frac{\partial Z}{\partial \bar{Y}_2} \cdot y_2 + \dots + \frac{\partial Z}{\partial \bar{Y}_m} \cdot y_m$$

where $y_1, y_2 \dots y_m$ are the small quantities $Y_1 - \bar{Y}_1, Y_2 - \bar{Y}_2 \dots Y_m - \bar{Y}_m$. Hence if we ignored the involved character of $\bar{Y}_1, \bar{Y}_2 \dots \bar{Y}_m$ in relation to the observed quantities, we should derive

$$\begin{aligned} [\epsilon(Z)]^2 &= \left(\frac{\partial Z}{\partial \bar{Y}_1} \right)^2 [\epsilon(Y_1)]^2 + \left(\frac{\partial Z}{\partial \bar{Y}_2} \right)^2 [\epsilon(Y_2)]^2 + \dots \\ &\quad + \left(\frac{\partial Z}{\partial \bar{Y}_m} \right)^2 [\epsilon(Y_m)]^2 \\ &= \left[\left(\frac{\partial Z}{\partial \bar{Y}_1} \right)^2 \left(\frac{\partial Y_1}{\partial \bar{X}_1} \right)^2 + \left(\frac{\partial Z}{\partial \bar{Y}_2} \right)^2 \left(\frac{\partial Y_2}{\partial \bar{X}_1} \right)^2 + \dots \right. \\ &\quad \left. + \left(\frac{\partial Z}{\partial \bar{Y}_m} \right)^2 \left(\frac{\partial Y_m}{\partial \bar{X}_1} \right)^2 \right] [\epsilon(X_1)]^2 \\ &\quad + \dots \\ &\quad + \left[\left(\frac{\partial Z}{\partial \bar{Y}_1} \right)^2 \left(\frac{\partial Y_1}{\partial \bar{X}_n} \right)^2 + \left(\frac{\partial Z}{\partial \bar{Y}_2} \right)^2 \left(\frac{\partial Y_2}{\partial \bar{X}_n} \right)^2 + \dots \right. \\ &\quad \left. + \left(\frac{\partial Z}{\partial \bar{Y}_m} \right)^2 \left(\frac{\partial Y_m}{\partial \bar{X}_n} \right)^2 \right] [\epsilon(X_n)]^2 \\ &= \sum_{i=1}^{i=n} [\epsilon(X_i)]^2 \sum_{j=1}^{j=m} \left[\frac{\partial Z}{\partial \bar{Y}_j} \cdot \frac{\partial Y_j}{\partial \bar{X}_i} \right]^2 \end{aligned}$$

This result differs in general from that previously obtained, and shows that the process on which it is based is fallacious. Thus the transformation from observed to related quantities gives a result the precision of which must be obtained by a single direct operation, and not by corresponding consecutive operations.

8. There are, however, particular transformations to which the foregoing statement does not apply. The conditions which must be satisfied by these will be obtained by comparing the results expressed in §§ 6 and 7. These become identical if the coefficients of $\frac{\partial Z}{\partial Y_j} \cdot \frac{\partial Z}{\partial Y_{j'}}$ in the former are equated to 0.

Hence we have $\frac{1}{2} m(m-1)$ conditions of the form

$$\sum_{i=1}^{i=n} [\epsilon(X_i)]^2 \frac{\partial Y_j}{\partial X_i} \cdot \frac{\partial Y_{j'}}{\partial X_i} = 0$$

in which $j \neq m$, $j' \neq m$, and $j \neq j'$.

9. Thus, for example, let $Z = \phi(\xi, \eta)$, where $\xi = f_1(x, y)$, $\eta = f_2(x, y)$, and x, y are quantities directly determined with equal precision, so that $\epsilon_x = \epsilon_y$. The above condition becomes

$$\frac{\partial \xi}{\partial x} \cdot \frac{\partial \eta}{\partial x} + \frac{\partial \xi}{\partial y} \cdot \frac{\partial \eta}{\partial y} = 0$$

Hence if the curves $\xi = c_1$ and $\eta = c_2$ in the xy plane intersect orthogonally, the precision of Z , for all forms of the function ϕ , can be derived from that of ξ and η .

Or again, the case may be considered of three quantities directly determined with equal precision. Here $Z = \phi(\xi, \eta, \zeta)$ and $\xi = f_1(x, y, z)$, $\eta = f_2(x, y, z)$, $\zeta = f_3(x, y, z)$. The conditions to be satisfied are

$$\frac{\partial \xi}{\partial x} \cdot \frac{\partial \eta}{\partial x} + \frac{\partial \xi}{\partial y} \cdot \frac{\partial \eta}{\partial y} + \frac{\partial \xi}{\partial z} \cdot \frac{\partial \eta}{\partial z} = 0$$

$$\frac{\partial \eta}{\partial x} \cdot \frac{\partial \zeta}{\partial x} + \frac{\partial \eta}{\partial y} \cdot \frac{\partial \zeta}{\partial y} + \frac{\partial \eta}{\partial z} \cdot \frac{\partial \zeta}{\partial z} = 0$$

$$\frac{\partial \zeta}{\partial x} \cdot \frac{\partial \xi}{\partial x} + \frac{\partial \zeta}{\partial y} \cdot \frac{\partial \xi}{\partial y} + \frac{\partial \zeta}{\partial z} \cdot \frac{\partial \xi}{\partial z} = 0$$

and show that if the measured quantities are represented by the coordinates of a point in space, and if the surfaces $\xi = c_1$, $\eta = c_2$, and $\zeta = c_3$ cut one another orthogonally, the intermediate process is legitimate. And generally it appears that quantities derived by an orthogonal transformation from equally precise observations can be treated as if they were themselves actually measured quantities.

10. The simple case of a linear binomial form will illustrate

what has been said. Suppose $Z = \lambda\xi + \mu\eta$, where $\xi = lx + my$, $\eta = l'x + m'y$. Then

$$Z = (\lambda l + \mu l')x + (\lambda m + \mu m')y$$

$$\therefore [\epsilon(Z)]^2 = [(\lambda l + \mu l')^2 + (\lambda m + \mu m')^2] \epsilon^2$$

But $[\epsilon(\xi)]^2 = (l^2 + m^2) \epsilon^2$; $[\epsilon(\eta)]^2 = (l'^2 + m'^2) \epsilon^2$

Hence if ξ and η were treated as independently measured quantities we should have

$$[\epsilon(Z)]^2 = [\lambda^2(l^2 + m^2) + \mu^2(l'^2 + m'^2)] \epsilon^2$$

which is erroneous unless $ll' + mm' = 0$, i.e. unless the axes, considered rectangular originally, remain so on transformation.

II. The method which has been illustrated in § 4 is instructive. I consider the case of two measured quantities x and y of which the mean errors are ϵ_x and ϵ_y . Let ξ and η be two functions of x and y , so that

$$\epsilon_\xi^2 = \left(\frac{\partial \xi}{\partial x}\right)^2 \epsilon_x^2 + \left(\frac{\partial \xi}{\partial y}\right)^2 \epsilon_y^2$$

$$\epsilon_\eta^2 = \left(\frac{\partial \eta}{\partial x}\right)^2 \epsilon_x^2 + \left(\frac{\partial \eta}{\partial y}\right)^2 \epsilon_y^2.$$

Then combined errors of equal probability are given by

$$\begin{aligned} \text{Const.} &= \frac{(\delta x)^2}{\epsilon_x^2} + \frac{(\delta y)^2}{\epsilon_y^2} \\ &= \left(\frac{\partial x}{\partial \xi} \cdot \delta \xi + \frac{\partial x}{\partial \eta} \cdot \delta \eta\right)^2 / \epsilon_x^2 + \left(\frac{\partial y}{\partial \xi} \cdot \delta \xi + \frac{\partial y}{\partial \eta} \cdot \delta \eta\right)^2 / \epsilon_y^2 \\ &= (\delta \xi)^2 \left[\left(\frac{\partial x}{\partial \xi}\right)^2 / \epsilon_x^2 + \left(\frac{\partial y}{\partial \xi}\right)^2 / \epsilon_y^2 \right] \\ &\quad + (\delta \eta)^2 \left[\left(\frac{\partial x}{\partial \eta}\right)^2 / \epsilon_x^2 + \left(\frac{\partial y}{\partial \eta}\right)^2 / \epsilon_y^2 \right] \\ &\quad + 2 \delta \xi \cdot \delta \eta \left[\frac{\partial x}{\partial \xi} \cdot \frac{\partial x}{\partial \eta} / \epsilon_x^2 + \frac{\partial y}{\partial \xi} \cdot \frac{\partial y}{\partial \eta} / \epsilon_y^2 \right] \end{aligned}$$

Now it is easily proved that

$$\frac{\partial x}{\partial \xi} = J \frac{\partial \eta}{\partial y}, \quad \frac{\partial y}{\partial \xi} = -J \frac{\partial \eta}{\partial x}, \quad \frac{\partial x}{\partial \eta} = -J \frac{\partial \xi}{\partial y}, \quad \frac{\partial y}{\partial \eta} = J \frac{\partial \xi}{\partial x}$$

where $J = \frac{\partial(x, y)}{\partial(\xi, \eta)} = \frac{\partial x}{\partial \xi} \frac{\partial y}{\partial \eta} - \frac{\partial y}{\partial \xi} \frac{\partial x}{\partial \eta}$

Hence the previous expression becomes

$$\begin{aligned}\text{Const.} &= J^2(\delta\xi)^2 \left[\left(\frac{\partial\eta}{\partial y} \right)^2 / \epsilon_x^2 + \left(\frac{\partial\eta}{\partial x} \right)^2 / \epsilon_y^2 \right] \\ &+ J^2(\delta y)^2 \left[\left(\frac{\partial\xi}{\partial y} \right)^2 / \epsilon_x^2 + \left(\frac{\partial\xi}{\partial x} \right)^2 / \epsilon_y^2 \right] \\ &- 2J^2\delta\xi \cdot \delta y \left[\frac{\partial\eta}{\partial y} \cdot \frac{\partial\xi}{\partial y} / \epsilon_x^2 + \frac{\partial\eta}{\partial x} \cdot \frac{\partial\xi}{\partial x} / \epsilon_y^2 \right] \\ &= J^2(\delta\xi)^2 \epsilon_\eta^2 / \epsilon_x^2 \epsilon_y^2 + J^2(\delta y)^2 \epsilon_\xi^2 / \epsilon_x^2 \epsilon_y^2 \\ &\quad - 2J^2\delta\xi \cdot \delta\eta \left[\frac{\partial\xi}{\partial x} \cdot \frac{\partial\eta}{\partial x} \epsilon_x^2 + \frac{\partial\xi}{\partial y} \cdot \frac{\partial\eta}{\partial y} \epsilon_y^2 \right] / \epsilon_x^2 \epsilon_y^2 \\ \therefore (\delta\xi)^2 / \epsilon_\xi^2 + (\delta\eta)^2 / \epsilon_\eta^2 &= \text{const.}\end{aligned}$$

on division by $J^2\epsilon_\xi^2\epsilon_\eta^2/\epsilon_x^2\epsilon_y^2$ (considered constant), if the condition

$$\frac{\partial\xi}{\partial x} \cdot \frac{\partial\eta}{\partial x} \epsilon_x^2 + \frac{\partial\xi}{\partial y} \cdot \frac{\partial\eta}{\partial y} \epsilon_y^2 = 0$$

is satisfied. This for the case $m=n=2$ agrees perfectly with the general conditions for independence previously found. The method employed here has the advantage that it indicates the nature of the function which the condition fulfils.

Oxford: 1901 March 2.

Observations of Leonids, 1900 November 15-16, made at the Royal Alfred Observatory, Mauritius.

(Communicated by T. Folkes Claxton.)

No.	Observer.	1900. Mauritius Civil Time.				Apparent size (in Star Mag- nitudes).	Dura- tion in secs.	Colour.	Train.	From		To	
		d	h	m	s					R.A.	Dec.	R.A.	Dec.
1	O.	15	0	25	11	> 1	2	Blue	5 secs.	101° - 15°		112°	0°
2	O.		0	56	21	2	1½	Bluish	Slight, 5 secs.	112 + 30		131	+ 20
3	P.		2	27	56	2	1	Bluish	None	112 + 30		124	+ 40
4	Or.		2	56	39	> 1	2½	Bluish	Long, 2 secs.	146 0		105	+ 48
5	W.		3	23	36	2	1½	White	Slight, ½ sec.	146 + 10		135	+ 3
6	W.		4	3	51	2	1	Bluish	None	160 - 11		163	- 20
7	W.		4	14	55	1	½	Bluish white	None	177 - 50		190	- 58
8	W.	16	0	56	44	1	1	Red	None	128 - 28		139	- 24
9	W.		0	15	0	1	1	Bluish white	1½ sec.	110 + 8		109	+ 20
10	O.		2	30	11	1½	½	Bluish	Slight	131 + 22		145	+ 15
11	O.		2	43	10	2	2	Bluish white	1 sec.	161 - 27		139	- 40

Watch was kept by four observers from November 13^d 23¹/₂^h to 14^d 2^h, and by one observer until 14^d 4^h. No *Leonids* were seen, although the weather was favourable.

From 14^d 20^h to 22^h 30^m watch was kept by one observer at intervals: from 15^d 0^h to 3^h continuously by three observers, and by four observers until 4¹/₂^h (daylight). Clouds at frequent intervals throughout.

15^d 0^h 48^m. Moon rose from behind cloud.

15^d 1^h 35^m. Large amount of cloud in neighbourhood of radiant, rain falling heavily to northward. None fell at observatory.

15^d 1^h 45^m. Rain extending from north to west. Lunar rainbow developed during this shower.

Watch kept by two observers on 16th, and at intervals by one observer on November 17.

Initials: W., O., Or., P.=Messrs. Walter, N. V. Olivier, L. N. Olivier, and Piveteau.

*Observations of the Partial Eclipse of the Sun 1900 November 22
made in Western Australia.*

(Communicated by W. Ernest Cooke, Government Astronomer.)

The partial eclipse of the Sun was observed at the Perth Observatory, W.A., on 1900 November 22. Instrument 10-inch refractor.

G.M.T. of first contact	November	21	19	37	26	82
„ last	„	„	22	06	38	28

The Moon's edge passed the first of two small spots at 19^h 52^m 50^s.28.

Observations of a solar blackened bulb and a dry bulb thermometer in a Stevenson's screen were taken at the observatory at Carnarvon, near Shark's Bay, and at a small island in Shark's Bay, as nearly as possible in the central path. These observations are enclosed herewith.

Photographs were also taken at various times during the eclipse. The negatives are preserved, but no special measurements have been made on them.

Greenwich Mean Time.	Perth Observatory.			Faure Island, Shark's Bay.			Carnarvon.		
	Solar Max.	Dry in Vacuo. Bulb.	Differ- ence.	Solar Max. in Vacuo.	Dry Bulb.	Differ- ence.	Solar Max. in Vacuo.	Dry Bulb.	Differ- ence.
h m	°	°	°	°	°	°	°	°	°
18 00	...	...	...	141°3	83°0	58°3	...	...	...
15	...	...	...	141°0	82°4	58°6	...	...	...
30	...	...	...	140°2	81°8	58°4	...	...	...
45	...	...	...	138°7	81°9	56°8	...	...	...
19 00	...	69°2	...	137°4	81°1	56°3	138°4	81°3	57°1
10	...	...	...	136°4	80°3	56°1	...	...	...
15	...	...	...	...	...	...	135°1	81°7	53°4
20	...	...	...	135°3	79°8	55°5	...	...	...
30	121°8	70°0	51°8	126°0	78°6	47°4	129°4	81°9	47°5
35	122°6	69°6	53°0	124°9	79°0	45°9	...	...	...
40	121°2	70°7	50°5	129°8	79°0	50°8	...	...	...
45	120°5	69°0	51°5	125°2	78°3	46°9	120°8	80°0	40°8
50	121°0	69°6	51°4	124°0	78°1	45°9	...	...	...
55	118°1	69°0	49°1	124°1	77°8	46°3	...	...	...
20 00	116°0	69°0	47°0	120°3	77°2	43°1	113°7	78°8	34°9
05	112°0	68°2	43°8	118°8	76°7	42°1	...	...	...
10	107°9	68°6	39°3	116°8	76°8	40°0	...	...	...
15	104°5	68°6	35°9	116°3	75°9	40°4	99°9	78°0	21°9
20	102°3	68°4	33°9	112°4	75°8	36°6	...	...	...
25	99°1	68°0	31°1	110°0	75°4	34°6	...	...	...
30	96°1	67°6	28°5	...	...	...	93°5	76°8	16°7
32	...	...	...	104°0	74°8	29°2	...	...	...
35	92°0	67°0	25°0	102°3	74°3	28°0	...	...	...
40	88°2	66°5	21°7	99°2	73°9	25°3	...	...	...
45	84°5	66°4	18°1	95°0	74°0	21°0	84°0	75°7	8°3
50	81°0	66°3	14°7	91°0	73°4	17°6	...	...	...
55	78°4	66°0	12°4	87°0	73°1	13°9	...	...	...
21 00	76°8	66°2	10°6	82°6	72°6	10°0	77°9	74°7	3°2
03	...	...	...	80°3	72°4	7°9	...	...	...
05	76°3	66°0	10°3	79°0	72°4	6°6	...	...	...
07	...	...	...	78°0	72°3	5°7	...	...	...
10	77°0	66°0	11°0	77°0	72°1	4°9	...	...	...
12	...	...	...	77°0	72°0	5°0	...	...	...
15	78°6	66°2	12°4	77°5	72°3	5°2	74°6	74°0	0°6
18	...	...	...	78°6	72°0	6°6	...	...	...
20	80°3	66°1	14°2	79°5	72°0	7°5	...	...	...
22	...	...	...	80°6	72°0	8°6	...	...	...

Greenwich Mean Time.	Perth Observatory.			Faure Island, Shark's Bay.			Carnarvon.		
	Solar Max. in Vacuo.	Dry Bulb.	Differ- ence.	Solar Max. in Vacuo.	Dry Bulb.	Differ- ence.	Solar Max. in Vacuo.	Dry Bulb.	Differ- ence.
h m									
21 25	83°0	66°0	17°0	82°3	72°1	10°2	...	...	...
27	...	...	...	84°0	72°0	12°0	...	...	...
30	85°7	66°0	19°7	85°7	71°8	13°9	77°0	74°0	3°0
33	...	...	...	87°2	72°0	15°2	...	...	...
35	88°1	66°0	22°1	88°7	71°9	16°8	...	...	...
38	...	...	...	90°2	72°0	18°0	...	...	...
40	90°7	66°4	24°3	91°5	72°0	19°5	...	...	...
42	...	...	...	92°3	72°0	20°3	...	...	...
45	91°8	66°4	25°4	93°9	72°1	21°8	80°0	74°0	6°0
47	...	...	...	94°7	72°2	22°5	...	...	...
50	93°0	66°3	26°7	96°0	72°2	23°8	...	...	...
52	...	...	...	96°4	72°0	24°4	...	...	...
55	93°2	66°2	27°0	97°2	71°8	25°4	...	...	...
57	...	...	...	98°0	72°0	26°0	...	...	...
22 00	93°4	66°1	27°3	98°3	71°7	26°6	91°8	74°0	17°8
02	...	...	...	98°6	71°6	27°0	...	...	...
05	93°1	66°1	27°0	98°6	71°6	27°0	...	...	...
07	...	...	...	98°8	71°4	27°4	...	...	...
10	92°1	66°0	26°1	98°2	71°2	27°0	...	...	...
12	...	...	...	98°0	71°2	26°8	...	...	...
15	...	...	...	97°4	71°1	26°3	82°3	73°8	8°5
20	...	...	...	95°6	71°0	24°6	...	...	...
25	...	...	...	93°1	70°7	22°4	...	...	...
30	...	...	...	90°2	70°3	19°9	...	...	...
35	...	...	...	86°7	70°3	16°4	73°5	72°7	0°8
38	...	...	...	83°7	70°3	13°4	...	...	...

Barometer, Faure Island, Shark's Bay. Height above M.S.L. about 25 feet.

G.M.T.	Uncorrected Baro.	Alt. Therm.	G.M.T.	Uncorrected Baro.	Alt. Therm.
h m	in.		h m	in.	
18 00	29°990	86°6	20 30	29°907	75°5
30	°980	85°7	21 00	°900	73°2
19 00	°952	84°0	30	°898	72°0
30	°936	82°0	22 00	°906	72°0
20 00	°925	79°8	30	°920	70°0

Wind fresh to strong, S.S.W. to W.S.W.

Position of Observing Stations.

	Latitude.	Longitude.
Perth Observatory	31° 57' S.	115° 51' E.
Faure Island, Shark's Bay	25 53	113 52
Carnarvon	24 54	113 39

Perth Observatory, W.A.:
1900 December 15.

Occultations of Jupiter and his Satellites, 1900 September 29,
observed at Windsor, New South Wales. By John Tebbutt.

This phenomenon was observed by me under very good conditions with the 8-inch equatorial refractor and a power of 74 diameters. The times of disappearance at the Moon's dark limb, which was well seen, were very satisfactorily observed. That part of the dark limb projected on the planet's disc was serrated in consequence of the lunar peaks, and appeared almost black by contrast. The disappearances of the satellites were, of course, not instantaneous, the times recorded being those at which the last rays vanished. Of the satellites, III. occupied about two seconds, I. about $1\frac{1}{2}$ second, II. about $1\frac{1}{4}$ second, and IV. about $1\frac{1}{2}$ second, in disappearing. Notwithstanding that the Moon's bright limb was steady and well defined, it was impossible to observe the actual reappearances of the satellites, the times being probably from one to two seconds late. Satellite IV. was very faint at the reappearance, and this phase for the planet's western limb was missed. The predicted phases for the planet had been kindly provided by Mr. C. J. Merfield, of Sydney. The following are the observed local sidereal and mean times of the phenomenon:—

	Sidereal Time. h m s	Mean Time. h m s
Disappearance of Satellite III.	20 1 32.0	7 30 47.2
Contact of Planet's Western Limb	20 11 58.9	7 41 12.3
Disappearance of Planet's Eastern Limb	20 13 27.7	7 42 41.0
Disappearance of Satellite I.	20 15 39.1	7 44 52.0
Disappearance of Satellite II.	20 18 29.1	7 47 41.5
Disappearance of Satellite IV.	20 32 44.9	8 1 55.0
Reappearance of Satellite III.	21 9 35.7	8 38 39.7
Contact of Planet's Eastern Limb	21 18 21.6	8 47 24.3
Reappearance of Satellite I.	21 19 37.6	8 48 40.0
Reappearance of Satellite II.	21 22 5.1	8 51 7.1
Reappearance of Satellite IV.	21 31 48.1	9 0 48.5

Observatory, Peninsula, Windsor, N.S. Wales:
1900 November 23.

THE FOLLOWING REPORTS OF OBSERVATORIES WERE RECEIVED TOO LATE FOR INSERTION IN THE ANNUAL REPORT OF THE COUNCIL :—

Melbourne Observatory.

Meridian Observations made with the 8-inch Transit Circle.

Observations in	R.A.	N.P.D.
Azimuth stars	299	134
Clock ,,	1676	...
List ,,	1160	1173
Total ...	3135	1307

The list stars were selected from the plates of the *Astro-photographic Catalogue* to be used for the reduction of these plates. The total number of this class of stars observed at Melbourne at least three times, up to December 31 last, was 3,534.

The separate results and annual catalogue for 1899 have been prepared, and the reductions of all meridian observations for 1900 are nearly completed.

The General Catalogue for 1890, which contains 3,100 stars, and includes all the observations made with the 8-inch Transit Circle since its erection in 1884 to the year 1893 inclusive, has also been completed, and is now undergoing a general revision and an independent re-computation of the precessions.

Astrophotographic Operations.—

Chart plates with triple exposures of 30 ^m each ...	45
Chart plates with single exposures of 60 ^m ...	56
Catalogue plates (Duplicate Series)	46
Test plates on South Polar region	31
Test plates on Oxford typical regions	10
Test plates for trials, centre, &c.	29
Plates for investigating magnitudes	9
Total number of plates obtained	226

Six chart plates with triple exposure, 7 chart plates with single exposure, and 2 catalogue plates have been rejected as defective.

The series of chart plates with single exposure of 60^m, covering the Melbourne zones of even degrees of declination, is practically completed, only some 12 rejected plates remaining to be obtained again. As the last Paris Conference did not come to

any definite conclusion as to the process and form to be adopted for the publication of the chart by the co-operating observatories, it is intended to initiate experiments to ascertain whether it will be possible here in Melbourne (both in regard to cost and excellence of work) to reproduce our chart plates for publication, taking for our model and standard the beautiful Paris charts.

Measurement of Plates.—See joint report.

Equatorials.—No systematic work has been done with the Great Telescope and other equatorials. These instruments have been used only occasionally for examination of comets and planets, and for visitors.

Photoheliograph.—Sixteen pictures of the Sun were obtained during the year on special occasions.

Terrestrial Magnetism.—Photographic registration of the variation of magnetic elements and absolute measurements have been carried on as in former years.

The measurement and reduction of magnetic curves of past years has been continued by four young computers.

7,911 day curves have been measured and reduced during the year 1900, including the records of 1881, 1884, 1885, 1886, 1887, 1888, 1889.

The total number of curves now measured is 12,206, which is about two-fifths of the whole amount required to bring the arrears up to the end of 1897.

Cloud Photography.—Sixty-five pairs of simultaneous pictures were taken for determination of cloud height and velocity. The reduction of cloud observations made for the International Meteorological Committee during the year 1897 and the measures of cloud photographs have been carried on by two young computers.

The reductions are well advanced.

Meteorological and Miscellaneous Work.—Amongst the general routine duties which have been carried on as in former years for public requirements are the following :—

The Time Service.—The meteorological service, which now includes 672 Victorian stations. The testing of surveying, nautical, and meteorological instruments, and rating of chronometers for the shipping, &c.

The observation and registration of tides.

Prolonged sickness prevailed amongst some of the members of the permanent staff in the course of the past year, and one of the temporary assistants died last December.

Measurement of the Sydney and Melbourne Plates of the Astrophotographic Catalogue. Joint Report for Sydney and Melbourne.

The measuring instrument made by Repsold & Söhne on the plan of Sir David Gill, which, as was announced in the joint report of last year, reached the Melbourne Observatory in January 1900, has been constantly employed in the systematic measurement of the catalogue plates since last March.

The verdict on this instrument, as far back as last April, was that "In point of construction and workmanship it fully bears out the reputation of the makers, and experience so far gained in Melbourne in working with it confirms the reality of all the advantages and capabilities ascribed to it by Dr. Gill."

All the adjustments were made with very little trouble within the degree of accuracy and in the manner described by Sir David Gill in *Monthly Notices*, vol. xlix. page 61 *et seq.*, and remained very constant.

This instrument is far easier, far less fatiguing, and far more satisfactory to work with than any other instrument previously used here for the measurement of plates. The rate of measuring has increased considerably with experience. At present about 170 stars can be measured in one hour, and, on an average, a plate containing 400 stars is measured in the direct and reverse position by two observers, each recording for the other in alternate periods of one hour, in one working day (about $6\frac{1}{2}$ hours), including the revision of measures differing by $0''.6$ or more, in the reverse and direct position, which discrepancy measures amount, at most, to 3 per cent.

The rate of measuring with the Melbourne micrometers is only one-third of that obtainable with the Repsold instrument.

Owing to this fact, and to unavoidable delay in pushing forward the measuring machine which is being made at the Sydney Observatory, we ordered last May another instrument from the Repsolds similar to the first, which we hope will reach Melbourne in a few months.

Thirty-six Sydney plates and fifty-one Melbourne plates have been completely measured, containing 49,697 stars.

The average number of stars on a single plate is, approximately, 1,000 for Sydney plates, and under 300 for the Melbourne plates.

As soon as the measuring bureau, which consists of six young ladies, is fully equipped with three quick-measuring instruments it is estimated, from the present rate at which the work is proceeding, that the work of the bureau for a year consisting of about 250 full working days will be probably represented by the measures of coordinates in direct and reverse position of some 300,000 stars.

Perth Observatory, Western Australia.

Once more, and it is hoped for the last time, the work of this observatory has been almost exclusively meteorological.

Some very useful work has, however, been accomplished, and the way made ready for the commencement of astronomical observations. In particular a book on the climate of Western Australia has been prepared. This has necessitated a thorough inspection of all records which were taken prior to the establishment of the observatory, checking all the additions, &c., and entering the results in ledgers. Its preparation has taken three or four years, as most of the officers' time was required for the routine work, but it is at last ready for the printer.

The routine meteorological work of course includes the issue of forecasts, which have been again very successful, even the public appearing to have some faith in them. The following were prepared during 1900 :—

1. For the whole State, issued at noon daily in connection with a weather map of the whole of Australia.
2. For the whole State, communicated to the Press daily at 8 P.M., in conjunction with a weather report from sixteen selected stations.
3. For the goldfields districts, telegraphed each evening at 8 P.M. to five daily newspapers circulated in that region.
4. For Perth and its immediate neighbourhood only, issued at 9 A.M. and exhibited in a pictorial form, similar to that of the London *Daily Graphic*.

The following were the percentage results for 1900 :—

	1	2	3
Correct	90	93	87
Partially correct	9	5	11
Wrong	1	2	2

The results of No. 4 were not tabulated, but the forecasts were almost invariably correct.

In astronomy the transit circle was used mainly for time purposes. Messrs. Joscelyne and Curlewis each made a determination of latitude from morning and evening circumpolars on three winter nights. Their results were respectively

$$31^{\circ} 57' 09''.42 \text{ and } 31^{\circ} 57' 09''.60,$$

which are in satisfactory accordance with one another and with the value already obtained by the Government astronomer, viz. $31^{\circ} 57' 09''.63$. None of these results have been corrected for errors of division.

The astrographic equatorial has been used almost entirely for the benefit of visitors. It was inevitable that many people

should wish to inspect the new observatory, and, in order to gratify as many as possible, parties of twelve to twenty were invited about three or four evenings every week. This popular state of affairs ceased on December 31, and in future only three evenings per month will be available for this purpose. A few students received instruction from the Government astronomer in practical astronomy during the early spring evenings.

The outlook now is decidedly more promising. At the request of the International Committee the Western Australian Government has agreed to allow the astronomer to take a share in the Photographic Durchmusterung, and additional assistance has been authorised. The zone -32° to -40° has been assigned, and it is probable that both astrographic telescope and transit circle will be in full work during the latter half of 1901.

Errata.

In Mr. H. C. Plummer's paper, page 146, Equation (3), for $\sin \delta \sin -\phi$
read $\sin \delta \sin \phi$.

In Annual Report (Progress of Meteoric Astronomy), page 246, 6th line from top, for perihelion read aphelion.